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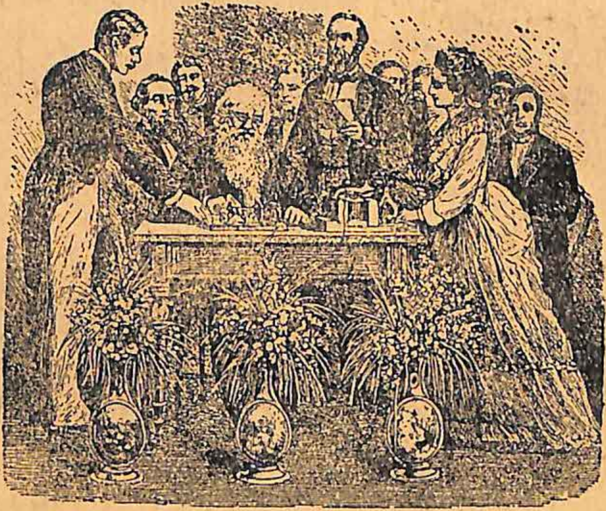
EGON LARSEN

Men Who Shaped the Future

Stories of Invention and Discovery



"Greeting and thanks to the
'Telegraph Fraternity throughout
" the world. Glory to God in the High-
est. on Earth Peace. Goodwill
to men.   S. F. B. Morse.

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STORIES OF INVENTION AND DISCOVERY

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EGON LARSEN

WITH EIGHT DRAWINGS

INSTITUTE OF EDUCATION FOR WOMEN
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1. *THE MAN WHO CROWNED KING COTTON*

GINS, GUNS, AND ELI WHITNEY

THE heavy coach turned into the drive leading up to Mulberry Grove Mansion, gleaming white in the brilliant autumn sun of South Carolina. A Negro footman appeared on the steps and bowed ceremoniously as the occupants alighted one after the other. 'Welcome home, Massah Miller,' he said to a man of about 30, with a pleasant but worried-looking face, who had jumped down first to help a lady to the ground.

'Welcome home, Missus Greene,' said the Negro.

The lady, although several years older than her companion, was of exceptional beauty. She had a sweet, round face with soft, quiet eyes and a delicate mouth; her voice was warm and motherly as she thanked the Negro for his greeting.

Last to jump from the coach was a young man of 27, who looked admiringly up to the tall gables of the Georgian house with its impressive columns forming the porch, as though he had not expected such a sight twelve miles from Savannah, in the midst of what he might have assumed to be impenetrable jungle. So this was 'the South' of the United States of America—the South of the year 1792.

'No, we are not savages, and this is not a jungle any more, Mr Whitney,' said the lady smilingly as though she had read the young man's thoughts. 'Sam, this is Mr Eli Whitney from New Haven,' she told the Negro. 'He has come as a tutor for Major Dupont's children.'

'Major Dupont is waiting in the drawing-room, Missus Greene.'

'He seems anxious to meet you at the earliest possible moment,' said the lady, and laughed. 'Come inside, Mr Whitney—and welcome to Mulberry Grove!'

There was something unusual about the young man. He was tall and slightly round-shouldered, with a large, sallow face. He had a rather long, hooked nose, and there was rarely more than the ghost of a smile in the corners of his mouth. His hair was black, and so were his eyes—deep-set, thoughtful, penetrating eyes. They made it difficult to size the young man up; he could have been called ugly but for those eyes. They belonged to a man who could not help thinking a great deal about the things he saw around him: the eyes of a dreamer, a visionary.

A stout, bald-headed man rose from his seat in the drawing-room. 'Major Dupont, our neighbour,' Mr Miller introduced him to Eli Whitney.

'Glad to make your acquaintance,' said the Major and shook hands with the young man. 'My friend Phineas Miller, who so ably manages Mrs Greene's estate, advised and helped me to get a Yale graduate for the education of my children. You men from Yale stick together, don't you?' He gave a short laugh.

'Yes, I met Mr Miller at Yale when I entered as a freshman,' Eli Whitney said politely. 'He graduated three years before me.'

'You can come with me straight away, Mr Whitney,' said the Major. 'We are agreed on the terms of your employment, are we not—all found and forty guineas per annum salary.'

Eli Whitney looked at the Major in surprise; then he turned to Phineas Miller: 'But surely the sum you mentioned in your letter to Yale was eighty?'

'Indeed it was,' said Miller, no less surprised. 'That was the sum you mentioned, Major, and it was on the strength of these terms that Mr Whitney undertook the journey.'

'Eighty guineas—good heavens, no!' said the Major. 'Why, I could never afford so much money for a tutor. Forty, my dear Miller, forty—that's what I said, and that's I'm going to pay.'

'Then there must have been some misunderstanding,' said Miller sharply. 'You are quite sure that forty is the limit to which you are prepared to go?'

'Quite sure, gentlemen.' He turned to go. 'You may decide to come to my house all the same,' he said to Whitney. 'Think it over.'

When Major Dupont had gone Miller told Eli Whitney how terribly sorry he was. Of course the Major had said eighty—but now that the new tutor had come all the way from Yale he tried to get him at half price. 'I only wish Mrs Greene could afford an instructor for her own children,' he said. 'Then you'd stay here at Mulberry Grove. But they will have to be content with the village school until they are older. Mulberry Grove can just about pay its own way at present.'

'This house looks as if you were millionaires here!'

'The house, yes—it was the residence of the British Governor until the people of Georgia threw him out and gave it to their own General Greene as a token of gratitude for his part in the War of Independence. Poor General Greene: he was only forty-four when he died of sunstroke six years ago; and poor Catherine: he left her with five children.'

'And then you took up your job as an estate manager. Mrs Greene keeps telling me how wonderfully efficient you are.'

'Catherine is a charming woman, but she knows little about the business side of the estate. Believe me, farming and planting in the South is a hard life.'

There was a moment's silence. Then Whitney said with a sigh, 'Well, there seems nothing left for me but to return up north. I shan't yield to the Major's blackmail. But I don't regret this journey. It was most kind of you and Mrs Greene to take me with you from New York so that I should not get lost on the way. I have seen new people and things, and gained experience —which is the best kind of knowledge.'

'I feel responsible for this,' said Miller. 'At any rate, don't decide anything without proper consideration. For the time being, will you remain with us at Mulberry Grove, as our guest?'

'You are very kind, Mr Miller. I will.'

Catherine Greene came in. 'I have heard what happened,' she said, and her soft, quiet eyes met Eli's. But I'm happy you'll stay.'

NAIL MANUFACTURER AGED 12

Eli Whitney was the oldest child in his family. His father, a man of more than 21 stone, was a farmer in Westborough, Massachusetts; his mother, ailing since the birth of the youngest of the four children, died when Eli was 12. Between them, he and his father managed as best they could without her.

It was then that Eli showed his exceptional skill with tools. There was a little lathe in his father's workshop, and here he spent many happy hours making or mending something. Farm work was not at all his province, but he never shirked his duties. In winter he had to feed sixty head of cattle every morning before setting out on his way to the village school.

For a while he concentrated on making violins in the workshop, and proved the high quality of his model by learning to play the instrument himself. When there was a dance in the neighbourhood he turned up with his fiddle, and made a few dollars on the side. Once his father complained that his watch was slow. Eli took it secretly to pieces—and was suddenly struck with horror: what if he could not get it together again? He worked in a frenzy, beads of cold sweat upon his forehead. He got it together. It worked. And it kept time.

All through his boyhood, the events of the American War of Independence provided the historical background to the little things in his daily life. There were political meetings, passionate outbursts of anger at the King's unjust treatment of his New England subjects; the Boston Tea Party, at which rebellious colonists, disguised and painted as Mohawk Indians, threw four-hundred chests of English tea into the harbour; tar-and-feather justice meted out to traitors to the cause of American liberty; and the formation of the colonists' own militia. Like all the other men in Westborough, Mr Whitney senior was given his rifle—only for it to be taken to pieces and studied in detail by Whitney junior. One day, many years ahead, this early familiarity with muskets was to become one of Eli Whitney's major assets.

The boycott of English goods imposed many hardships on the colonists. There was, for instance, a great shortage of such little things as nails. Eli asked his father if he would let him make some nails in the workshop.

'But, boy, you'd need a forge for that,' said his father.

'Of course I do. I've thought it all out. I've saved a few dollars, and I know an old man who could put up the forge for me.'

Farmer Whitney laughed. 'All right, if you think you're as clever as all that—go ahead. Nails are sure to fetch a good price.'

So the twelve-year-old mechanic manufactured nails. It was his first encounter with the problem of mass-production. He tried a number of systems of making the nails.

One evening he asked his father for one of the horses so that he could ride to a neighbouring town and hire a workman, as he was tired of working alone; besides, the job would be more profitable if the fire in the forge were used continuously.

He was gone for three days, and his father began to worry. When he returned he reported that he had travelled forty miles, had visited a number of workshops, and collected much information about other people's production methods; he had also hired a labourer.

Eli's father told him off for being absent without leave, and with the horse. But the boy's enterprising spirit made a great impression on him. The hired man stayed for three months; nails were made at great speed and sold at good prices, and only when the war ended and nails lost much of their value, did Eli stop making them. But he had his forge, and was ready to take up some other item. He looked around, and discovered that a new fashion had come in the wake of the Revolution; ladies no longer tied their bonnets with ribbons under their chins, but fastened them with three long pins.

So it was hat-pins for the young manufacturer. He developed his own technique for drawing out steel into fine, long pins—this special skill, too, was to prove its value in later years. And when hat-pins no longer were good business, he switched to walking-sticks turned on the lathe. 'He was remarkable for thinking and acting for himself as a boy,' his sister once said of Eli. 'I have heard it remarked that at the age of 12 he had more general information than *men* considered of the first standing in the country!'

THE STEPMOTHER

Eli was 14 when his father married again. The new mistress of the house was a widow, who brought two of her own ten children along. To the Whitney children she was just what they expected a stepmother to be. Her lack of love for the smaller ones made them cry for nights on end; to Eli, her ways were a wholesome lesson on the sort of attitude he would soon encounter in the outside world: mistrust, callousness, and egotism.

At 15, Eli fell ill. He developed a boil on the leg which grew worse and worse. It was harvest time; Whitney the elder was in the fields all day, and Eli was entirely at the mercy of his stepmother and one of her daughters. One day, the doctor had left a bottle of medicine which he was to take every hour. But no one came to give it to the patient. Eli knocked on the wall; nobody stirred. He knocked for two hours; then, weary with the effort, he fell asleep. An hour later he woke with a terrible thirst, and knocked again. No one came. Yet the stepmother and her daughter were in the house all the time. After five hours and a half, Eli's father returned home. Eli called him, and told him what he thought of this kind of nursing. The father went to his new wife and gave her a lecture she did not forget to the end of her days.

Her enmity towards the children of the man she had married showed itself everywhere. There was, for instance, the matter of the thousand dollars which Mr Whitney had set aside for Eli's college education. Eli had never left any doubt that he wanted that education; he was no good as a farmer, and only a university could give him the necessary basis for the development of his particular talents. His father was wise enough never to try to make a farmer out of him, and fair enough to give the boy all the chances he could. Hence the one thousand dollars.

But the stepmother grudged him the money, and tried to persuade her husband to withdraw his consent. Mr Whitney, however, remained firm. Eli was to have his college education—at Yale. The thousand dollars would pay for the actual education at the college; but there were years of preparation. How could he manage to study? He was eighteen now, and there was no question of his staying at the farm as a mere non-paying guest while preparing himself for college. His stepmother would have made his life unbearable.

By accident he was led to choose thesystem then generally in use among young people with little money but a great thirst for knowledge—that of teaching while being taught. A small town in the vicinity was looking for a schoolmaster. Again Eli borrowed his father's horse. This time, however, he was back the same day.

'Father,' he announced, still breathless from the ride, 'I've been accepted! Seven dollars per month and all found.'

'You mean your're going to be a schoolmaster at Grafton?'

'Yes, Father, that's what I've been accepted for.'

Mr Whitney shook his head. 'Why, Eli, you're in need of a school yourself! How can you teach?'

'But, Father, there are schools and schools. I want higher education. And I teach the three R's—surely I can do that!'

All the same, Eli prepared himself thoroughly for the job during the three weeks before school started. At the end of the year he was asked to teach for another winter. The money he earned paid for his own studies at Leicester Academy. So he went through the seasons, teaching and learning; but it took him five years to get through the curriculum prescribed for the entrance examination. It was stiff at Yale: the candidate had to be able to translate and analyse Latin and Greek passages picked at random, he had to be familiar with English grammar and arithmetic, and—most important—he had to present himself to the examining professors as an intelligent, well-spoken, and well-mannered young man.

JOURNEY WITH CATHERINE

Eli Whitney passed the examination and was admitted. New Haven appealed to him very much: Yale had impressed the whole town with its mark of culture and civility. There was no indication yet of the arrogance and rowdiness which were to become attributes of student life in the Old and the New World during the course of the nineteenth century; the young men of Yale in Whitney's time were simply the sons of hard-working farmers and merchants trying to acquire as much knowledge as possible for the future careers as lawyers or doctors, teachers or scientists. There was a library which could boast of a copy of Newton's great work, the *Philosophiae Naturalis Principia Mathematica*, presented by Sir Isaac himself; and a museum with a three-foot telescope, an orrery, an electrical induction machine, an alligator preserved in alcohol, an air pump, and a Red Indian *calumet*, a pipe of peace.

Eli enjoyed his years at Yale, but the money problem kept cropping up every now and then: the thousand dollars paid for the fees and board, but not for the extras. He incurred debts, and wrote urgent letters to his father asking for help. He did not ask in vain; but his father warned him that he would not be able to help him much after leaving college, and that Eli had better choose his future profession very carefully from this point of view.

He was 27 when he graduated in 1792. Whatever he may have fancied for himself as a profession, it could not have been one that would have made another financial investment necessary, such as that of a lawyer or doctor; he had to be content with a humbler station in life, one which brought immediate cash without further capital outlay—that of a private tutor to rich people's children. There was, at first, the prospect of such a job in New York; it fell through for some reason. At the same time, that letter from Mr Phineas Miller arrived, offering him a job with Major Dupont, and inviting him to travel south with himself and Catherine Greene; they were now in New York on business. Eli accepted.

'In four days I shall set out for South Carolina,' he wrote to his younger brother. 'The climate is unhealthy and perhaps I shall lose my health and perhaps my life, but I hope to return to you again some time or other.' Indeed, two of his college-mates who had gone to Georgia had died there. Whitney knew that there would be a radical change in his life once he had gone south; how radical no one, and Eli Whitney least of all, could have foreseen.

The journey south with Catherine Greene was an unforgettable experience for Eli. Here, for the first time, he came into contact with a woman of the great world—graceful, cosmopolitan, witty, with an easy manner that warmed his heart. Catherine, eleven years older than Eli, took a motherly interest in the friendly, wistful young man who looked like a big fledgling for the first time on the wind, a thousand miles away from his nest. To him, Catherine must have appeared as the ideal woman, herself perhaps out of the reach of his heart's desire, but a model of what the girl he would once want for his companion would have to be.

Did he fall in love with Catherine? He could not have answered that question himself. For as soon as he realized that Phineas Miller had older claims, and that she was on very familiar terms with the man who managed her estate, Eli Whitney withdrew to a position of respectful admiration. The young Yale graduate felt that he could vie for Catherine's affection neither with Miller, the trusted and valuable friend of the family, nor with the shade of the late General Greene, George Washington's most trusted comrade-in-arms and commander of the American revolutionaries' Southern armies. Who was he, Eli Whitney, to join such company? A little schoolmaster, a man who would probably never make a discernible mark in this world.

Five and a half days after setting out from New York the ship reached Savannah. How different was this country from Massachusetts and Connecticut in the north! The endless fields planted with rice, corn, and potatoes, the orchards with their oranges, pomegranates, figs and olives, the wooden houses baking in subtropical heat—it was another world.

A SIMPLE INVENTION

Josiah Stebbins of New Haven was Eli Whitney's life-long friend. He was the one to hear Eli's most secret thoughts and wishes; he was the ever-ready recipient of his friend's complaints, and his sympathetic adviser. Stebbins seems to have had very little private life of his own—at least there appears hardly a trace of it in the many letters that passed between the two friends—but was quite content to echo Eli's joys and sorrows.

Stebbins was, of course, looking forward to receiving Eli's account of his great adventure down south, and shared his friend's disappointment about the 'misunderstanding' concerning the wages offered by the Major. 'You know I always considered this a dam'd kind of world,' Eli wrote, 'and to say the truth, I have no great reason to change my opinion since I saw you. I find some, however, among the human species in this part of the world as well as in N. England who are not unworthy, among whom Mr Miller ranked. He has really treated me very much like a Gentleman. . . . Fortune has stood with her back toward me ever since I have been here.' Stebbins would soon see him back in New Haven, he promised, and then he would tell his friend the rest of the news.

Only two weeks later, however, Stebbins received another letter from Eli—written in an entirely different vein, cryptic and wildly optimistic at the same time.

'You must know, Brother Stebbins, I have become very expert in the Hocus-Pocus line,' he wrote. 'I already rank among the higher order of the conjurers. . . . '

And then, in the first week of July 1793, he was back in New Haven. But he was a different man from the quiet, somewhat lethargic schoolmaster who had set out to South Carolina. His eyes were sparkling, his movements were quick and purposeful. 'Dame Fortune has turned about at last,' he said as he shook Stebbins's hand, 'and for the first time her ladyship deigns to look upon me and smile!'

'Eli, won't you explain—'

And Eli explained. One day, Miller had taken him on a tour of the plantation. In the midst of a field Miller pulled up to talk to some of the workers. Eli looked around; the crop in this field looked unfamiliar to him. He asked Miller what it was.

'It's cotton, Mr Whitney. Never seen it before?'

'No.' Eli took a boll of the plant in his hands and looked at it. 'How is it harvested? Which part of it is used?' he asked.

The seed of the plant was covered with a greenish, velvety coat. 'It's this fibre which has to be removed and spun into yarn,' explained Miller. Eli tugged at it, trying to separate it from the seeds. Miller laughed. 'Not so easy, you see! We have a few special workers who can do that at speed.'

'Why not use a machine?'

'Look here, Whitney, you don't want to upset me, do you?

Well, don't talk to me about ginning cotton—that's what we call it. I hear that story all day long from my workers and overseers in the cotton fields. "If only we had a machine!"—they can't think of anything else.'

'Why not talk to me about it? I might have become a mechanic if I hadn't set my ambition on studying at Yale. But surely there must have been mechanics trying to invent a ginning machine!'

'There is a machine, if you must know. It looks like a clothes wringer and squeezes the seeds from the fibres. Its all right for the sea-island cotton with its long fibre; but it's completely useless for our short fibre here. Yet if someone invented a really efficient machine it would be a great thing—both for the inventor and for the country.'

Eli Whitney kept silent during the rest of the tour. For the next two or three days he went about Mulberry Grove deep in thought, every now and then taking a boll of cotton from his pocket and plucking at it wistfully. Eventually he asked Miller to listen to an idea of his. He produced a number of drawings and sketches.

'Here's your cotton gin,' he told Miller.

Miller, incredulously, glanced at the drawings. 'And how is it supposed to work?'

'There is a revolving cylinder here, behind a stationary breast-work; there are hundreds of sharp wire hooks coming out from the cylinder. These bristles are so arranged that they act like a whole battery of circular saws. Now the breast-work has grooves corresponding to the hooks, and when a cotton boll is picked up by the hooks the seed is held back by the breast-work while the fibre is carried through the grooves. The seeds fall into a hopper, and the cotton fibre is picked off the cylinder by an arrangement of fast-whirling brushes.'

Miller looked at the drawings with mounting interest. 'You mean the cotton is torn from the seeds—the brush whisking away the fibre while the seeds are collected in the hopper?'

'That's the idea.'

'Very simple.' Miller was still looking at the sketches. 'And who's going to turn the whole thing?'

'Anything or anybody: water-power, horses, workers. It does not need any skill—that should be a great advantage.'

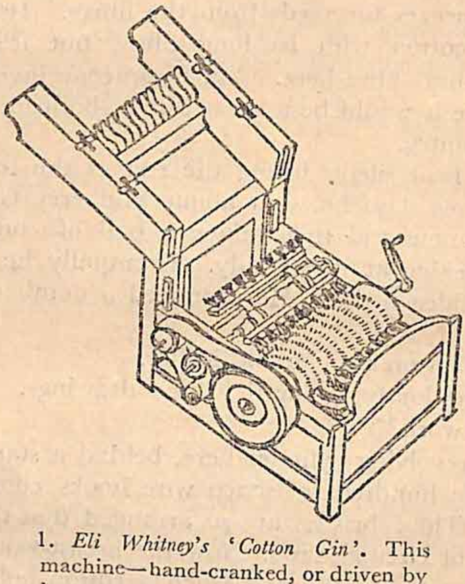
'And who would build such a machine?'

'I'll build a model straight away so that any mechanic could make copies.'

'My dear Whitney—there are no mechanics in the south.'

'Then I'll have the copies built in the north.'

'And have the machine patented?'



1. *Eli Whitney's 'Cotton Gin'*. This machine—hand-cranked, or driven by horse- or water-power—separated the cotton from its seeds.

'Of course—I would have forgotten that. I'll make the model, and start back north in a few days. But . . . I have no money to follow this idea up.'

'What would you say if I backed your invention with the necessary money and we went half and half?'

'I'd say I'm all for it. In fact, I couldn't do it without you. I'm not a business man. I can make that cotton gin, but the rest is up to you.'

THE AMERICAN INDUSTRIAL REVOLUTION BEGINS

There was nothing grand about the former British colonies which combined into the United States of America after their successful rebellion against the King's rule. These territories, clinging to the east coast, were a poor man's country. In the north, the soil was just good enough to keep a farmer and his family alive. There was no industry yet. In the south, vast tracts of excellent soil were waiting to be cultivated, but the shortage of man-power prevented the expansion of the farms. Rice, tobacco, and indigo were the main products; cotton was, as everybody agreed, a great potential source of wealth, but the harvesting of the fibre was too slow, and the product was almost as expensive as silk. So its cultivation was restricted to a small number of fields, and to the back garden for domestic use. And across the ocean, England was crying out for more and more cotton to feed its newly-invented manufacturing machines.

The position of the slaves was most interesting in this connexion. When Whitney first came to the south the slave population was no more than five per cent; in fact, slavery was on the point of dying. The price of black human flesh had sunk so low in the markets that many farmers thought of giving their Negroes full citizens' rights! A slave, they argued, has to be whipped into activity for his master, and he has to be fed even if there is nothing for him to do; as a free man, he will have to force himself to work if he wants to eat, and the farmer does not pay him if there is no work for him in a slump. It was not William Wilberforce's humanitarianism that made the southern American planters wonder if they should not free their slaves, but plain economic thinking. If cotton could be cleaned efficiently, things would be different: enormous areas could be cultivated, enormous armies of Negro slaves absorbed—and enormous fortunes made by the planters.

Eli Whitney spent two or three days in the shed at Mulberry Grove and made a model of his gin with the odd bits of material and the few tools he found there. His resourcefulness which he had developed as a boy when making nails and hat-pins stood him in good stead. The machine was tried out—with immediate success.

Whitney calculated from these trials that his cotton gin, operated by one man and a horse, could do as much work as fifty men with roller gins of the clothes wringer type—which, however, could not be used with the short South Carolina fibre anyway. In fact, his gin did the work of 180 manual labourers working without machines.

King Cotton's reign had begun.

Stebbins congratulated his friend on the invention.

'But I implore you to keep it a profound secret,' said Eli. 'I must get the patent first. Tomorrow I shall start for Philadelphia to take all the necessary steps. I might be able to see the Secretary of State, Mr Jefferson. He is extremely interested in new inventions.'

'You *are* aiming high, Eli!'

'Sure I am. Of course, something I cannot foresee may happen and defeat my plan; but I am so certain of success that you could count ten thousand dollars on this very table—and the money would not tempt me to give up my right and relinquish the whole thing.'

'To your success,' said Stebbins and raised his glass—they had met at Stebbins's house and were sitting in the parlour. 'I can hardly recognize you, Eli. You are a different man. When you left, you were just drifting; now you have found your way.'

'And I'll never lose it again,' smiled Eli Whitney.

He did see Mr Jefferson in Philadelphia, then the seat of the U.S. Government; but the granting of the patent took some months. Meanwhile, Whitney equipped a workshop in New Haven and collected a few mechanics; the first piece of work he made was a neat little model of his invention, to be submitted to the Patent Office on request.

That request came in the form of a long, personal letter from the Secretary of State Mr Jefferson: 'As the State of Virginia, of which I am, carries on household manufactures of cotton to a great extent, as I also do myself, and one of our great embarrassments is the cleaning of the cotton of the seed, I feel a considerable interest in the success of your invention for family use. Permit me therefore to ask information from you on these points:

has the machine been thoroughly tried in the ginning of cotton, or is it as yet but a machine in theory?' And he went on to ask about performance and efficiency of the machine, its production cost, and its labour requirements.

Whitney replied in detail, and three months later—a number of unforeseen technical difficulties had to be overcome in the workshop—he brought his model to Philadelphia. In March 1794, the patent was granted. 'I accomplished everything agreeable to my wishes,' he told his father in a letter. 'I had the satisfaction to hear it declared by a number of the first men in America that my machine is the most perfect and the most valuable invention that has ever appeared in this country.'

The road seemed clear and straight; at its end, Eli Whitney would take his place of honour beside James Hargreaves, the inventor of the spinning jenny, Sir Richard Arkwright, the inventor of the water-frame, and Samuel Crompton, the inventor of the mule (so called because it was a cross between Hargreaves's and Arkwright's machines)—the men who created the textile industry. Yet not even in his most ambitious dreams could Eli Whitney have foreseen that his simple invention would help to turn the poor man's country into the richest of the world; that the separation of the fibre from the seeds in the cotton plant would mean not only clothes for the whole world, but valuable oil from the seeds—for food and soap, grease and fertilizer; and that even the linter, or shell, removed during the processing of the seeds, would become a chemical raw material—for high-explosives, shatter-proof glass, writing-paper, varnish and a dozen other products.

Nor could he have foreseen that there was nothing but trouble and disappointment ahead for the creator of that great little machine, the cotton gin.

GINS FOR HIRE

The subscriber will engage to gin, in a manner equal to picking by hand, any quantity of the green seed cotton, on the following terms: viz. for every five pounds delivered him in the seed he will return one pound of clean cotton for the market.

For the encouragement of cotton planters he will also mention that ginning machines to clean the green seed cotton on the above terms will actually be erected in different parts of the country before the harvest of the ensuing crop.

Mulberry Grove, near Savannah,
March, 1794
Phineas Miller.

This advertisement in the *Gazette of the State of Georgia* marked the beginning of the use of the cotton gin. Miller had found an ingenious solution to the problem of how to exploit the market; for one of the big machines would have cost $400-500 to buy, and there would not have been enough buyers with so much cash in hand. This system of hiring out gins had several advantages. The 'fee' was to be paid not in money but in cotton; the machine delivered about one pound of fibre to three or four pounds of cotton with seed, but Miller offered one pound of the former only to every five of the latter, so the profit would be quite substantial, although the labour cost had to be deducted. Slaves were hired from their masters at two shillings a day for the men and one and sixpence for the women. That was common practice.

While Whitney was producing the machines at his New Haven workshop, Miller travelled up and down the country selecting and renting sites for the erection of 'ginneries' so that the planters willing to take up cotton cultivation would have a machine in their vicinity. In May 1794, Whitney returned to Mulberry Grove with a whole consignment of gins. Catherine was genuinely happy to see him back, radiating success and optimism. From all over the country, requests for ginning facilities arrived at Mulberry Grove; and so did visitors who wanted to see the new wonder. From each trip, Miller brought back new reports about the efficiency of the machine. 'The saving of labour exceeds our expectations!' he declared. 'Three hands can do the ginning and bagging of six hundred-weight per day! Two boys, or one old or lame hand and a boy can attend two gins at a time. Only one strong man is needed to pack the cotton.'

In an economic system based on slave labour, the problem of maintaining the old, the lame, and the children was formidable. The cotton gin helped to solve it. There was no longer any talk about granting the slaves their freedom. The expanding cotton production needed the whole slave community—the able-bodied and the young, the men and the women, the aged and the sick. We may well ponder over the double-edged character of technical progress: in America, the Industrial Revolution gave the dying slavery system a new lease of life which was to last for nearly another century; in England, it produced sweat-shops and child labour, slums and proletarian poverty, and turned beautiful Lancashire into the cotton-manufacturing country of the 'dark satanic mills'. But history knows neither 'good' nor 'bad'.

Miller & Whitney—the cotton gin firm—needed a great deal of capital for its rapid expansion, and here Catherine's help was invaluable. She approved of borrowing substantial sums, pledging her estate as security; she believed in Whitney's invention and in Miller's efficiency to exploit it. Yet the need for capital was so great that Miller could not resist embarking on a land speculation that promised a quick, large profit.

A handful of rich and influential men misused the administration of Georgia for their own improper purposes to effect a 'land-grab' of about thirty-five million acres in the West—what is now Alabama and Mississippi. Secretly, these men had already re-sold most of the 'Yazoo' country, as it was called, to Northern buyers. When the true facts came to light, the administration cancelled the sale, and the records of the evil transaction were publicly burned.

In his zeal to inject new capital into the firm, Miller had participated in the Yazoo speculation, and lost all. It never rains but it pours. He and Whitney had hardly got down to assessing the damage when a message arrived from New Haven: the workshop had caught fire and was completely burnt down. To make matters still worse, Whitney was unable to go to the scene of the disaster at once; he was down with malaria. When he arrived at New Haven at last, hardly able to stand on his legs, he found all his property in ashes: 'My shop, all my tools, material, and work equal to twenty finished cotton machines all gone. . . .'

THE PLANTERS WON'T PAY

The fire of enterprise that had glowed in Eli Whitney's heart was nearly extinguished. Listlessly, he sat in Stebbins's home, his eyes sunk, his cheeks paler than ever. 'I'm not cut out for this kind of business,' he muttered. 'I should have become a schoolmaster, not an inventor.'

'I wish I'd never started the thing,' he said.

'Nonsense,' said Stebbins. 'You'll soon be on top of the world again, you'll see. Is your invention any the worse for the fire?'

Miller wrote him a letter which pulled him out of the depths of despair. 'I will devote all my time, all my thoughts, all my exertions and all the money I can earn or borrow to encompass and complete the business we have undertaken. . . . It shall never be said we have lost an object which a little perseverance could have attained. I think, indeed, it will be very extraordinary, if two young men, in the prime of life, with some share of ingenuity, with a little knowledge of the world, a great deal of industry, and a considerable amount of property should not be able to sustain such a stroke of misfortune as this, heavy as it is.'

Miller's confidence re-kindled the spark in Eli Whitney. He, too, took up new loans, and within a few months the workshop was re-built. New machines were again shipped south. But there had been a long gap in the production schedule, and this was used by a number of planters in the South to instal some crude, locally-made imitations of Whitney's cotton gin.

The simplicity of the machine—it's great advantage—now proved great danger. Anybody who had ever seen it in operation knew how it functioned—'It has teeth that work thro' slats, and a brush', the boys of South Carolina and Georgia told each other. Why, the farmers thought, should two people reap all the benefit in the whole country? Let's make our own cotton gin, and keep all the cotton it produces!

These trespassers had little fear of legal prosecutions; instead of packing their unauthorized machines away and apologizing when Miller tried to stop them, they sought to justify their actions. 'This is a kind of tax we're made to pay when we have our cotton ginned by you people,' they told Miller. He threatened them with lawsuits. They laughed. 'Let your bailiffs come—we'll show them the way home!'

They failed to appreciate the simple fact that it was Whitney's invention that had enabled them to grow cotton at all; their only concern was the ransom to which, in their opinion, they were being held by Miller and Whitney. The hard-headed men who had fought for their freedom from the King's tax collectors were not going to stand any such nonsense from their own countrymen!

Enormous sums were at stake. In 1795, the entire South produced eight million pounds of cotton; in twelve years' time the crop was to increase to eighty millions. At the same time, the price of the pound of cotton rose by fifty per cent. Had the firm of Miller and Whitney received their due from each farmer it would have earned several million dollars per year. But there were many others who nibbled away the profit that should have rightfully flowed into Miller's and Whitney's pockets.

There was, for instance, a man by the name of Edward Lyon. It was said that he disguised himself as a woman to get near one of the cotton gins and study its construction; but it is more likely that he bribed a number of workers near Savannah to tell him the details of the machine. Then he set up his own workshop and made gins, which he sold to the planters. Now they were rich enough to buy the machines.

At the same time, complaints came from England. There, the spinners had been used to the long, sea-island staple; the new, short fibre was unfamiliar to them, and they believed the vicious rumour put out by the anti-Whitney planters that the 'patent gin' destroyed the cotton fibre. The rumour rebounded across the Atlantic, and the cotton brokers buying for England refused to pay the full price for cotton ginned with the Whitney machine.

'You must go to England,' Miller told Whitney, 'and clear up matters on the spot. It is indispensable that we break down that English prejudice. We can't hold out another year if this difficulty is not removed. Time is short—and our capital is running out.'

Things would have turned out differently if Whitney had gone to England. But he never went. First it was the necessity of attending to the New Haven workshop which kept him back; then another severe attack of malaria; and eventually there just wasn't enough money to finance his journey. In vain, Miller offered as much as thirty per cent interest for a loan of a thousand dollars.

No money came forward; and Whitney was unable to travel to England.

AMERICA NEEDS MUSKETS

There was, of course, another road—that to the law courts. Miller & Whitney sued the chief trespasser, Mr Lyon. But the trial developed into another disaster. The imperfections of the patent law enabled the imitator to get away with the flimsy excuse that he had 'improved' on Whitney's gin. Besides, Miller made a vital mistake; he invited the judge twice to dine with him and used the opportunity to 'prepare' him for the case. The jury did not like these practices at all—they were too reminiscent of the bad old days of British rule. The verdict went against the plaintiffs.

That year, 1797, looked as if it would see the last of Whitney's cotton gin, and of the firm of Miller & Whitney. The two men, still young in years, saw the end of their enterprise which had begun so hopefully and now appeared to be drawing to a close with such heartbreaking disappointment. They were both in the same boat . . . or were they? Phineas Miller was still Catherine Greene's manager and trusted friend; more than that: he was now her husband. They had married in 1796.

We can only guess how Eli Whitney felt about this. We know that he had been very much attracted to Catherine. The two never spoke about love. But now, as Phineas Miller took Catherine for his wife, Eli Whitney reproached himself for having let him take Catherine without a word, without a fight. From that moment, he looked upon himself as an old bachelor, and bemoaned his loneliness. If he met other girls he must have compared them with his lost Catherine, and found them wanting. His private unhappiness combined with the disappointment he had suffered as an inventor, and he withdrew from other people, wallowing in self-pity and dejection. He felt that he was a failure. 'All is doubt and uncertainty,' he confessed to Stebbins. '"To be or not to be" is a question which I cannot decide. . . .'

Somehow he pulled out of the depths of despair. Life had to go on. He still had his workshop, now idle for lack of capital. In

1798, the political situation worsened; it looked as though the United States would be going to war with its former friend and ally, France. Congress debated the military weakness of the country. Whitney wrote a letter to the Secretary of the Treasury, Oliver Wolcott. He told him that he still had a number of workmen who could work wood and metals, tools and machines for making muskets. He offered to produce ten or fifteen thousand of them.

It was a shot in the dark, and Eli Whitney could not have really thought of all the consequences if the Government accepted his offer. He had never made a musket before, and the number he suggested must have sounded quite astronomical at a time when every single rifle or pistol was made laboriously by hand by one workman who did the whole job from start to finish.

To his surprise, Mr Wolcott replied that he would like to give Whitney a contract. America was in desperate need of muskets; if war with France came it would mean facing a large army of citizens called upon to fight by the famous *levée en masse* decree of the Convention, the first summons to total war—ordering the young men to take up arms, the married ones to forge weapons and carry munitions, the women to make uniforms and tend the wounded, the children to make lint for bandages, and the old men to act as propaganda speakers in the public squares. France would indeed be a formidable enemy. American musket production was pitifully small; the Government armoury set up in Springfield, Massachusetts, in 1794 had not been able to deliver more than 245 by 1796, and just over 1,000 by 1798!

No wonder, then, that the U.S. Government welcomed such offers as Whitney's. In June 1798, he received his contract for delivery of ten thousand 'stand of arms' (the complete equipment of a soldier, comprising musket, bayonet, ramrod, wiper, and screw-driver) by the end of September, 1800. One of the two contracting parties, and perhaps both, must have believed in miracles; how could a private manufacturer produce ten thousand rifles in little more than two years—considering that Springfield had made exactly 245 in the same period?

However, Whitney got five thousand dollars advance on signature of the contract, with another five thousand to come when the first

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had been spent on production preparations. Altogether $134,000 were to be paid to Whitney for the muskets.

'Stebbins, I'm saved!' he cried when he met his old friend back in New Haven. 'Saved from ruin! Bankruptcy was staring me in the face, disappointment tripped me up at every step I made. I was a miserable failure, loaded with debt, without means of support. Now I can think again without worrying.'

'You mean, Eli, you aren't worrying how you're going to make those ten thousand stand of arms in two years?'

'Not yet, Stebbins, not yet. I've got my plan.'

THE BEGINNINGS OF MASS PRODUCTION

When Eli Whitney invented the cotton gin he did not know that he was setting the immense machinery of America's Industrial Revolution in motion. When he began to plan the manufacture of his ten thousand guns he had no idea that he was about to create the modern system of mass production.

Right from the start, he ran into bad luck. He had to get his iron and steel from the public stores; but an epidemic of yellow fever had disrupted the entire Government business in Philadelphia, and the administration had moved to Trenton. After many inquiries, he at last met an iron-founder who promised to deliver ten thousand musket barrels ready for boring and finishing.

Meanwhile, he looked for a factory site complete with a water mill as source of power. It took him longer than expected to secure such a site; he found it near New Haven, a place called Mill Rock, with ample water supply. But there were no suitable buildings yet, and he had to start from scratch. Even the dam for the mill had to be built. It took him until the middle of January 1799 to get his factory ready. It was 72 feet by 30 feet and two stories high; close to the factory he had another building equipped as a boarding-house for his twenty workers, with a housekeeper and two kitchen maids. But then came the severest floods New England had ever experienced, while the works of the barrel manufacturer was frozen up so that he could not deliver. The Government was beginning to get nervous; nearly a year had gone by, and not a musket was in sight. Whitney, of course, was not the only contractor, though the biggest; and fierce circular letters were sent out from Philadelphia: 'The sooner a contractor discontinues a business to which he is unequal, the better it will be for him and the public.'

Whitney had to ask Mr Wolcott, the Secretary of the Treasury, for patience and more money. The Secretary sent his newly-appointed inspector of musket manufacture to Mill Rock to find out what was going on.

The inspector arrived one morning when Whitney was snowed under with work. 'Oh, tell him to go away and leave me alone,' Whitney told the workman who called him to his office where the gentleman from Philadelphia was waiting. But then his prudence got the better of him; he wiped his sweating, greasy face, and went to his office.

'I'm Eli Whitney,' he said as he entered.

'No need to tell me that,' said the visitor and laughed.

'Wadsworth!' cried Whitney. 'What on earth——'

'I thought this would surprise you.. Allow me to introduce myself: Captain Decius Wadsworth, United States Inspector of Muskets.'

They shook hands. Wadsworth was an old friend of Whitney's a fellow-student from Yale. They talked about the happy days at New Haven and about the cotton gin—Wadsworth knew a good deal about it.

'Now look here, Eli,' he said eventually, 'won't you show me some of your muskets?'

'I can't,' replied Whitney. 'I haven't got them . . . only one.'

'You're joking, aren't you? You're not going to tell me that you've made only one musket in two years?'

'Sure, Wadsworth. That's what I'm telling you. Here it is.' And he took a rifle down from a hook on the wall, and handed it to his visitor.

Captain Wadsworth looked at it, examined its parts, snapped the lock. 'Not bad,' he said. 'I'd even go so far as to say it's better than any of the military muskets I've seen so far, American or foreign. I don't have to try it out on the shooting-range to see that. But—but where are the others?'

'Let me explain. This is just a specimen piece. The rest will be just like it . . . exactly like it. You see, I'm not going to have dozens of gunsmiths working at their benches, each making one complete musket after the other. Instead, I've been building tools and machines to make the individual parts. If each individual workman had to form and fashion every part according to his own fancy I should get an infinite variety of sizes and proportions, and if some part or other is faulty the whole musket has to be returned to the man who made it. Do you follow me?'

'I certainly do. As a matter of fact, we have in our armoury hundreds of muskets in need of repair because one or the other part is unusable. Why can't we employ mechanics who are able to make these parts uniformly?'

'That requires very long practice, Wadsworth; and we haven't got the time. There are no more than a few dozen mechanics in the whole of the United States who have such unfailing hands and eyes.'

'Well, what is your answer to the problem then?'

'My primary object is to make the tools which can fashion the work accurately, uniformly, and quickly: tools and machines which give every part of the musket its correct proportions, as independently as possible of the skill of the individual workman. You could compare this system to the process of engraving from a copper plate—any number of impressions taken from the plate will be exactly alike!'

Captain Wadsworth scratched his head. 'Sounds all right, Whitney,' he said. But will it work out in practice?'

'Tell Mr Wolcott that I shall come up to Philadelphia in a fortnight's time, and put the proof on his desk.'

THE SECRET OF THE FIFTEEN PARCELS

Two weeks later, Eli Whitney arrived at the Treasury Office in Philadelphia. Captain Wadsworth was expecting his visit, and had arranged for a meeting with Mr Wolcott.

'There are fifteen parcels in my coach,' Whitney, told his friend. 'Can you have them sent up to Mr Wolcott's office?'

Two soldiers carried the parcels up, and Eli Whitney spread them out on the table. The Treasury Secretary came in with a number of officers and officials. Captain Wadsworth had prepared them for an interesting demonstration, but in his heart of hearts he was not so sure that the whole thing would not end in a disaster for his friend.

Whitney opened the fifteen parcels. Each of them contained ten similar musket parts—ten barrels were in one parcel, ten lock-plates in another, ten butts in a third, ten guards in a fourth and so on; screws and other connecting parts emerged from a box.

'Now, gentlemen,' said Eli Whitney, 'will you please choose one piece from each parcel, and hand the parts to me.'

They did so, and Whitney went to work. Right under the astonished eyes of the assembled men he joined the parts together; and their surprise grew with every minute, for the object that took shape in the inventor's hands was a complete rifle.

'Ready,' he said at last, and handed the weapon to Mr Wolcott, who took it incredulously. Eli Whitney turned back to the table. 'Now please choose another piece from each parcel,' he said. Within a few minutes, the second musket had taken shape—indistinguishable from the first. Then came the third and the fourth, until all the parcels were empty, and ten muskets lay before the Secretary.

'This is sorcery,' smiled Mr Wolcott. 'Do you mean to say that all the musket parts you are making are so accurate that they are interchangeable?'

'Quite so, Mr Secretary.'

'And that, for instance, if some part of a musket became damaged or unusable, you could supply another part just like it, which could be fitted into the musket without having it sent back for repairs?'

'Exactly.'

'Has this system of interchangeable parts ever been tried before, Mr Whitney?'

'Not for anything like a musket. I have heard that the English tried it out for lowering the manufacturing costs of pulleys for the Navy; and I am also told that some mechanics in France attempted to use it on a very small scale.'

'Is there any reason, Mr Whitney, why this system should not be applied to the making of other mechanical goods—say, for instance, watches and clocks?'

'None whatsoever.'

'Gentlemen,' said the Secretary and turned to the people in his office, 'I think this is a very great acquisition for the United States. I feel entire confidence in your project, Mr Whitney. I shall not hold you to the strict terms of the contract regarding time, and I will help you to get sufficient financial security. Now tell us a little more about your system.'

Whitney and the others sat down informally around the table with the ten muskets, and he explained. In his factory he used such things as 'filing jigs' and fixtures, inventions which held the piece of work while guiding the tool with great accuracy; stencils with up to a dozen holes which enabled the workmen to bore the holes in the work-piece in exactly the right places; mechanical stops fixed to the lathe which prevented the workman from turning the piece in hand too little or too much; and a number of dies and moulds for various parts. There was no doubt in the minds of his listeners that this system went far beyond its immediate purpose of making rifles quickly and with as little skilled labour as possible.

Eli Whitney returned to Mill Rock in the glory of his success. The people of New Haven were not slow in appreciating his achievements; a number of well-known citizens—merchants, doctors and lawyers, most of them Yale graduates—offered him a loan as a token of their pride and trust in him. He was now able to expand his works; soon, forty men were busy making muskets, bayonets, and ramrods.

Yet he was a lonely man. He hardly ever left Mill Rock, working without a break. 'I am often impatient and unhappy that I progress so slowly,' he told Stebbins (now New Haven's postmaster), who came to see him. 'At other times I look around and see that I have, after all, done a great deal, and I feel more satisfied. I know that my factory is superior to any in America—I'm even vain enough to think that it is equal to any in the world.'

'You must be a happy man, Eli.'

'That is just the point—I am not. I am a solitary old bachelor. I have no friends except you. I work hard all day, and when I lie down at night I find that I have left ten times as much undone as I have accomplished during the day——'

'Eli, you ought to get married.'

'I know, Stebbins. I think a great deal about it. But whom should I marry? Where can I find the girl? Out here at Mill Rock? It's a vicious circle, and I cannot find the way out.'

'You must find it. You are 35 now. You are driving yourself too furiously. One day you'll discover that life has slipped by, and all you'll have left is a factory and a handful of dollars.'

Among the innovations which Eli Whitney brought into the world was one of which he had no reason to be proud: he created in himself the prototype of the modern high-pressure business man—a human being who sacrifices his private life to his work. It was no accident that Whitney turned into that type of man as the eighteenth century turned into the nineteenth, and the age of leisure into that of industry.

JUSTICE FOR THE GIN

There was little in the way of business success that Whitney did not achieve in these years; he had made the tide of his fortunes turn for good. The year 1798 had seen him on the brink of bankruptcy; two years later, by his own exertions, he had made his name one of the greatest in America. The Government was so impressed by his new method that it accepted Mr Wolcott's recommendation to extend Whitney's contract period to five years, and treble his advance.

During those two years of building up Mill Rock, however, the cotton gin and the firm of Miller and Whitney had been dormant. Whitney wanted to forget the whole thing, together with the struggles and disappointments of the past; Miller saw that he was battling against overwhelming forces. 'I have been so long and so continuously placed in the very vortex of error and of prejudice, of complaint and abuse respecting our unfortunate cotton gins,' he wrote to Whitney, 'that some new evidence against a suspicion of insanity would seem requisite, to enable me to stand thus alone in opposition to public opinion.' The worst thing was that he could no longer keep Mulberry Grove for Catherine and himself; they were so much in debt that it had to be sold by auction.

Just about that time—1800—the English cotton buyers were beginning to revise their judgement of the staple ginned by the Whitney machines, and favourable reports came from Liverpool. The South Carolina cotton exporters were consequently asking for more 'genuine' cotton gins. Encouraged by this success, Miller campaigned for the amendment of the patent law which had protected the trespassers. It was altered, and there was no more sanctuary for the offenders. Miller attacked them with lawsuits. He won a number of them.

Now that the cotton gin was again on the march, Miller and Whitney were once more the target of much public indignation as the owners of a monopoly. Georgia's governor called it 'a manifest injury to the community . . . a cruel extortion on the gin holders . . . Georgia and South Carolina, where cotton appears to be becoming the principal staple, are made tributary to two persons'. And he expressed a feeling which still dominates American public life to this day: 'Monopolies are odious in all countries but more particularly so in a government like ours. . . . The patentees, it is supposed on the lowest calculation, will make in the two States one hundred thousand dollars.'

Should an inventor be deprived of the fruits of his labour because the idea of a monopoly was 'odious' to the American people? There was a way out of the dilemma: the Government could buy the patent rights from the inventor, and put the invention at the disposal of the people. In September 1801, Miller wrote to Whitney that this plan was now taking shape, and that his presence was necessary as he was the inventor, and as there was going to be a good deal of hard bargaining with the authorities.

Whitney packed his bags and started on his way to the South. But he went first to Washington, the new capital of the United States, and asked for an interview with a man who had always held him in high esteem—Thomas Jefferson, now President of the United States. He was received immediately.

'What can I do for you, Mr Whitney?' asked the President.

The inventor explained that he was on his way to Columbia to prevent the patent rights in his cotton gin being taken over by the Legislature of South Carolina for a mere pittance in view of the prejudice and ignorance with regard to the machine. 'They have always hated me down south, Mr President, because I'm a northerner, and they do not like northerners to be cleverer than southerners,' Whitney said with growing indignation. 'They will try to prove that I never invented the cotton gin, or that my machine injures the fibre. I'm not after the money, Mr President, but I want my name cleared. Can you help me?'

Thomas Jefferson sat down at his desk, and began to write, reading out the words while he put them on paper: 'Mr Whitney is at the head of a considerable gun manufactory in Connecticut, and furnishes the United States with muskets, undoubtedly the best they receive. He has invented moulds and machines for making all the pieces of his locks so exactly equal, that take 100 locks to pieces and mingle their parts and the 100 locks may be put together as well by taking the first pieces which come to hand. Mr Whitney is now on his way to South Carolina on the subject of his gin. . . .'

And so the President's letter went on—a grand recommendation, addressed to whoever cared to read it, that showed Eli Whitney not as the man who 'held the south to ransom' with his cotton gin, but as 'the Artist of his Country', as Jefferson called him, a man of whom all America should be proud.

With this letter, Whitney went on his way. He met Miller in Columbia, and they decided to ask for a hundred thousand dollars for their patent rights, 'a sum far below the value of the invention', as they argued. 'The use of the machine here is amazingly extensive and the value of it beyond all calculation. It may without exaggeration be said to have raised the value of seven-eighths of all the three southern States from 50 to 100 per cent!'

But the Legislature voted only fifty thousand dollars, and even that sum was granted grudgingly and mainly because the President himself seemed to think so highly of 'that Mr Whitney'. All around him, the inventor felt a great deal of hostility towards himself. Yet 'his modest and even diffident manner', as an eye-witness put it, 'procured him some friends—the value of his invention had procured him many more. But he still had many prejudices and difficulties to overcome. Some doubted the originality of the invention, though his proofs were strong and they could not point out any other inventor; others doubted the utility of the invention. Truth and public spirit, however, prevailed. The Legislature purchased Mr Whitney's patent right for the use of the inhabitants of the State.'

South Carolina got its fifty thousand dollars back by imposing a tax of fifty cents on every 'row of teeth' in every gin to be paid by its users.

For Miller and Catherine the money was a godsend. How things had changed in these ten years! Then, Eli Whitney had found help at Mulberry Grove, a penniless tutor without a job; now, Mulberry Grove was no longer, its former master was deeply in debt, while Eli Whitney was a prosperous industrialist. Poor Phineas Miller was not permitted to enjoy for very long the freedom from worry which the money brought him and his wife at last; he died in 1803, leaving Whitney with an increased sense of loneliness and abandonment. There was the bitter feeling of 'too late' in Whitney's heart as the Circuit Court of Georgia, in 1806, awarded him damages against a trespasser with these enthusiastic words—how he wished that Phineas Miller had lived to hear them!—

'With regard to the utility of this discovery, the court would deem it a waste of time to dwell long upon this topic. Is there a man who hears us, who has not experienced its utility? The whole interior of the southern states was languishing and its inhabitants emigrating for want of some object to engage their attention and employ their industry, when the invention of this machine at once opened views to them which set the whole country in active motion. From childhood to age, it has presented to us lucrative employment. Individuals who were depressed with poverty, and sunk with idleness have suddenly risen to wealth and respectability. Our debts have been paid off, our capitals increased; and our lands are treble in value. We cannot express the weight of obligation which the country owes this invention—the extent of it cannot now be seen—some faint pre-sentiment may be formed from the reflection that cotton is rapidly supplanting wool, flax, silk, and furs in manufactures, and may one day profitably supply the use of specie in our East-India trade. Our sister states also participate in the benefits of this invention; for besides affording the raw materials for their manufactories, the bulkiness and quality of the article afford a valuable employment of their shipping.'

Justice had at last come for Eli Whitney's cotton gin.

ELI MARRIES

Whitney longed to have a family. As he did not have one of his own he 'borrowed' one from his sister—in the shape of her three boys. His nephew Philos was 10 when he arrived at Mill Rock to live with him. He did not like it at all at first. 'I now Set Down to Let you know that I am in good helth and i hope you engoy the same,' the boy wrote to his mother. 'I have not ben to school Sense I hav ben here and I cannot read nor write one Half as well as i did when i came heare To lieve and i do not wish to live heare. . . .'

Yet this unwilling young visitor was the only observer at Mill Rock who recorded what the first mass production factory looked like, for Eli Whitney never bothered to describe it in detail. 'Thare is a drilling machine and a boureing machine to bour berels and a screw machine and too great large buildings, one nother shop and a stocking shop to stocking guns in, a blacksmith shop and a trip hammer shop and five hundred guns done,' wrote young Philos.

The wonders of Mill Rock seem to have overcome his dislike of the place. And Uncle Eli was such a kind, affectionate man; only one thing he could not stand—bad language. 'Such a habit is not only criminal but will forever prevent your becoming interesting and respectable in conversation,' Uncle Eli warned him and his two brothers, who joined Philos some time later at Mill Rock.

The family idyll came to an end, however, when Whitney fell seriously ill in 1810, at the age of 45. He had to take an enforced rest; the pressure he had kept up for over ten years must have grown too strong. Recovering slowly, he surveyed the strange path of his career. He was still a convalescent when he wrote to a fellow-inventor, Robert Fulton: 'The difficulties with which I have had to contend have originated principally in the want of a disposition in Mankind to do justice. My invention was new and distinct—it stood alone and was not interwoven with anything before known. . . . Demagogues made themselves popular by misrepresentation and unfounded clamours. . . . There was a time when there were but few men in Georgia who dared come into court and testify to the most simple facts in their knowledge relative to the use of the machine. In one instance I had great difficulty to prove that the machine had been used in Georgia, and at the same moment there were three separate sets of this machinery in motion within fifty yards of the building in which the court sat, and all so near that the rattling was distinctly heard on the steps of the court-house!'

He was on his feet again when the event which America had dreaded for so long happened: war broke out. But the enemy was not France; it was England again. Whitney wrote at once to the Secretary of War, surveying the armament situation, and offering his works, 'the most respectable private establishment in the United States for carrying on this important branch of business', for arms manufacture by the 'new methods' he had invented. He got a contract for the delivery of fifteen thousand muskets within ten months. But a new, formidable enemy made life extremely difficult for Whitney: Captain Irvine, Wadsworth's successor as superintendent of the military stores, and Commissary General of Purchases. This man misused his vitally important position during the war for an attempt at gaining control over the allocation of funds and employment of personnel so that a certain musket model, in which he was financially interested, should replace all the others. To this end, he tried to harass the private contractors out of business.

Whitney took up the gauntlet. He challenged Captain Irvine in every possible way. The Captain had made a serious mistake in assuming that the tall, well-dressed, quiet gentleman from Mill Rock who came to see him in Washington could not be a gunsmith with practical experience at the work-bench. But Eli Whitney knew more about making muskets than Captain Irvine, with all his financial interest in the rival musket, would ever learn. Irvine tried to get the War Secretary on his side in his private feud with Whitney. The War Secretary sent his own inspector to Mill Rock, and after reading his report ordered Captain Irvine to 'let Whitney go on with his contract'.

The Captain refused to yield; he collected all kinds of evidence against Whitney. The climax of their private war coincided with that of the war between Great Britain and the U.S.A. in the summer of 1814: the English captured the city of Washington; the Government fell, and Captain Irvine with it.

Whitney went on making muskets for the American army.

The war was drawing to an end when the saddest piece of news Whitney had ever received reached him in his works. Catherine had died in September 1814. Eli Whitney was stricken with unhappiness and remorse. Had she not urged him for years to visit her after Phineas Miller's death? His excuse had been the same he had kept using for himself whenever he bemoaned his lack of a private life: business pressure. Now, her last letters assumed more and more importance in his mind. 'I wish to God, my dear friend, you were married,' she had written shortly before her death.

He fell ill again—escape into sickness, as modern psychology would put it. But now he formed the decision to end his own misery as a 'solitary old bachelor'; Catherine's death must have broken the evil spell at last: only when she had gone for ever was his mind free to choose a companion among the living.

His choice fell on Henrietta Edwards, 31 years old, a girl from one of the most eminent New England families. She had known Eli since they were children, but they had not met for twenty years. It was not love that brought them together, but urgency: for Henrietta it was high time to get married—being a plain and not very brilliant girl she was in great danger of remaining a spinster, for in those days 31 years was an almost forbidding age for marriage; Eli Whitney, on the other hand, at 52, could no longer pick and choose.

Like so many marriages of convenience this one, concluded in January 1817, was much happier than might have been expected. Henrietta was a devoted wife, and Eli was a most attentive husband. They had four children, and it looked as though his private life was at last blessed by fate.

Five happy years passed by. But in 1822 his health gave way, and from then on his life was a heroic struggle against pain and misery—a struggle which only a lifelong fighter such as Eli Whitney could have endured for so long. It is a tragic thought that today the affliction to which he fell victim—a gland disease—can be cured by a simple operation in a short time. Then, it was incurable, and there was no remedy for the suffering.

For nearly three years Eli Whitney battled with all his strength of mind against the dark forces in his body. His family and business were prospering, and even on his sick-bed he kept inventing new machine tools. The last of his technical sketches, concerning 'a further invention for drawing, forging, and fashioning metals based on an entirely new principle', is dated January 1825. 'I shall test the principle by actual experiment in the course of the present year,' he wrote to a friend. It was the idea of 'driving a trip hammer by a belt or strap'.

But the 'present year' was all too short for Eli Whitney. On 8 January 1825, he died at the age of nearly 60. He never saw the incredible transformation which America's South was undergoing during the last years of his life—a wilderness had turned into the great cotton belt yielding unheard-of wealth, worked by an army of Negroes which was now fifty per cent of the entire population: all this through the impact of his cotton gin, the simple invention of a young man without a job.

2. *DOT AND DASH CONQUER THE WORLD*

SAMUEL MORSE AND THE TELEGRAPH

IT was a pleasant surprise for the passengers on board the *Sully* when one of their fellow-travellers turned out to be an amateur conjuror. They had sailed from Le Havre on 1 October 1832, bound for New York; the *Sully* was a good sailing ship, yet the crossing would take at least three and possibly four weeks, with nothing to see all day but the sea and the sky, nothing to hear but the swish of the waves and the whistling of the wind in the sails, interrupted by the monotonous sound of the ship's bell. Soon they would know each other's stories, jokes, and complaints by heart, and the sea yarns of Captain Pell, the ship's master, would grow taller and taller as the days went by and the boredom became less and less tolerable.

So it was indeed a stroke of good luck that Dr Jackson was able to entertain them with some conjuring acts. Charles T. Jackson was a young chemist and physician from Boston, who loved to invent new tricks based on the scientific discoveries of an age rich in chemical and physical achievements.

After dinner on the first evening of the crossing, Dr Jackson brought his paraphernalia to the saloon. The passengers grouped themselves in front of the little table on which Dr Jackson had put his magic wand and top hat, and the performance began.

A SCIENTIFIC TOY

The conjuror started with the usual tricks—making cards appear and disappear, and taking out of his top hat things which had definitely not been there a few seconds before. . . . 'And now watch carefully, ladies and gentlemen. . . . . Nothing here, nothing there . . . abracadabra—*voilà*': and the bountiful hat produced another egg. Captain Pell laughed so much that his whiskers were all of a twitter. The gentlemen grinned knowingly as if they were quite well aware how it was done, but did not want to spoil the fun by revealing it. The ladies clapped whole-hearted approval.

'May I now show you something altogether different, ladies and gentlemen?' continued Dr Jackson. 'A little experiment from the realm of science that will astonish you greatly. This—,' and he held up a piece of metal shaped like a horseshoe, 'this is a piece of soft iron which I will transform into an elctro-magnet. Have you ever heard of that discovery? The natural philosophers Sturgeon in England and Oerstedt in Sweden have found, quite independently from one another, that such a piece of iron will become magnetic if you wind a coil of wire around it, and send an electric current through the wire. When you stop the current, the iron is no longer magnetic. An amazing discovery, ladies and gentlemen! I have seen Professor Ampère in Paris experiment with the elctro-magnet, and I will now repeat his demonstrations for your benefit.'

Dr Jackson wound some insulated copper wire around the iron horseshoe, and joined the ends of the wire to a galvanic battery. There were a few nails on the table; as soon as the horseshoe was brought within a distance of some inches, the nails flew up and clung to it. Dr Jackson disconnected one of the wires from the battery; and the nails dropped back on the table.

The experiment, successful as it was, did not get nearly as much applause as the trick with the egg produced out of an apparently empty top hat. Somehow the magic of the electro-magnet was not magical enough for the passengers of the *Sully*.

'A pretty scientific toy,' said Captain Pell. 'Do you think it could be of practical use some day, Dr Jackson?'

'Scarcely,' said Dr Jackson, and packed his horseshoe in its box. The passengers thanked him and filed out of their cabins to go to bed.

Only one of them went up on deck, to be alone with his thoughts under the star-spangled, silent dome of the sky. He had been Dr Jackson's most attentive spectator, and during the experiment with the horseshoe a sudden idea had seized him which was to change the whole of his life—more radically and suddenly than any man's life had ever been changed by a brainwave.

The name of the man who was leaning over the breast-rail, staring at the stars and the waves, was Morse—Samuel Finley

Breese Morse. He was an artist, a well-known American painter returning to New York from three years' travel and study in France and Italy. He was a tall, slim man, with soft eyes and rather long, greying hair, nearly 40 years of age. Life had not always been kind to him. His father was a Congregationalist village parson in Connecticut who had not been able to give his son many advantages. Samuel had had a bitter struggle in his early youth, trying to help his parents by earning a few extra dollars. One of the means by which he did this was to draw portraits of his schoolmates.

His father's circumstances grew a little easier as the years went by, and Samuel, who appeared to have great artistic talents, was sent to London to study at the Royal Academy. On his return, he took a studio in Boston, waiting for people who wanted their portraits painted. But there were no customers. So he packed his palette, colours, and canvasses in a rucksack and toured the provinces, painting portraits at fifteen dollars apiece.

During one of these trips the artist, who was in his early thirties, met beautiful Lucretia Walker, and they fell in love and married. She was Samuel Morse's lucky star; with Lucretia advising, helping, and encouraging him, he succeeded in getting customers and securing public commissions, such as that for a portrait of President Monroe. Within a few years, he became one of America's most popular artists, and was elected president of the National Academy of Design.

Then, after seven happy years, Lucretia died suddenly. Morse was heartbroken; he found that he could not concentrate on his work without her. So he sought oblivion in a long journey to Europe, in an extensive pilgrimage to the museums of France and Italy, the cathedrals and churches adorned with the masterpieces of the past, and the places where their creators had lived and worked.

Now he was on his way back to America to resume his career as an artist. But the moment Dr Jackson made his horseshoe attract the nails something totally unexpected had happened in Samuel Morse's brain. He has recorded for posterity the idea that suddenly flashed through his head; an idea destined to bring much suffering and endless struggles to its author—and one of the greatest benefits to mankind. Here it is, phrased in Morse's own words:

> 'If the presence of electricity can be made visible in any part of an electrical circuit closed by an electro-magnet, I see no reason why intelligence may not be transmitted instantaneously by electricity!'

With that idea, the electro-magnet ceased to be just a 'pretty scientific toy'.

THE ELECTRIC EASEL

Morse realized that the world was waiting for the gift of a modern instrument of communication. The industrial revolution was in full swing. Steam-power was ousting horse-drawn traffic on land and sailing vessels at sea; industrial manufacturing processes were superseding manual labour; more and more capital was being invested in industry, demanding profit from a rapid exchange of goods among the nations. The whole structure of human society had begun to change completely, and the pace of daily life was growing faster and faster. Only the transmission of news—or 'intelligence', as Morse called it—had remained almost unchanged for the last two thousand years. In fact, the messenger system of the Roman Empire had worked better and faster than the slow postal services of 1832.

There was, however, something new in communication, the optical telegraph invented by a Frenchman, Chappe, in 1792, which had come into general use in France, England, and Germany during the first half of the nineteenth century. But it had many shortcomings. It was expensive because it needed a great number of operators and semaphores, spaced at sight distances across the country: it was unreliable because it was a fair-weather and daylight instrument; and it could not keep secrets—anybody could get to know the semaphore code and read the messages. This was perhaps the main reason why the Chappe telegraph was never used for private messages, but remained a governmental and administrative institution. Besides, the prohibitive cost would have prevented the private citizen from using it; it has been estimated that the transmission of an ordinary telegram must have cost about £8-10. And as it was unlikely that the Western world could have adopted the drum telegraph of Africa's Negroes, there was in fact no system of communication able to meet the great demand which made itself felt everywhere.

Morse thought about this the night after Dr Jackson's performance. In the morning he asked if he could have all his meals in his cabin for the rest of the journey. The steward agreed, in the hope of getting an extra large tip. So Morse shut himself up in his cabin. In vain his fellow passengers tried to find out what he was doing there; he let no one in, and all the steward was able to tell them was that the artist was drawing sketches.

This was indeed what he did. Working incessantly, he filled his sketch-book with drawings of what he called 'the electric telegraph'. Little did he dream that these sketches would one day find a home in the National Museum in Washington, and that they would be much more valuable than all the pictures he ever painted! Only when Sandy Hook came in sight did Morse emerge from his cabin, carry his portmanteau, and obviously very impatient to get ashore.

'Well, Professor,' said Captain Pell, 'surely you can tell us now what you have been doing all through the crossing?'

'Captain,' replied Morse earnestly, 'if one day you hear of a new, world wonder called the electric telegraph—remember that that invention was made on board your ship!' And he walked down the gangway, leaving the astonished Captain to make of that what he could.

Back in New York at last, Morse felt little desire to paint, and failed to renew his old connexions, which could have brought him well-paid work. He began to give drawing lessons to keep body and soul together, but his diet was rarely more luxurious than tea and biscuits. He had not a cent left for buying material to make a proper model of his invention. Even tea and biscuits had to be crossed off the menu if at any time the wealthy fathers of his pupils forgot to pay the fees. He would ask a young student:

'Well, my boy, how are we off for money today?'

'Why, sir, I expect to bring some next week.'

'Next week! I shall be dead by that time.'

Eventually, some old friends of his got him a position as an art professor at the New York City University. The pay was small, but it enabled him to start building a model of the electric telegraph.

As an artist he thought in terms of his profession: thus, an ancient easel became the basis of the first telegraph. Other parts of the model were a primitive electro-magnet which he had wound himself, the wheels of a wooden clock that was too old to work any longer, a single-cell galvanic battery, a length of wire, a roll of paper strip, and a pencil end. After tinkering with these components for some weeks he got his model assembled, and tried it out.

It worked; but not reliably, and only over very short distances. The idea was that when Morse connected one end of the wire to the battery, the electro-magnet attracted a small piece of iron playing the part of the armature. The pencil end was attached to it, and as the paper strip was pulled along underneath the pencil by a weight and clockwork gear, slanting strokes appeared on it. These strokes were Morse's first 'code', representing the letters of the alphabet.

'SUCCESSFUL EXPERIMENT WITH TELEGRAPH'

For two long years, Morse wrestled with this primitive apparatus. All it did was to show that the principle of the invention was sound; but Morse was not a mechanic, and was unable to improve it so that it would transmit messages over a reasonable distance.

That problem, the conquest of distance, caused Morse a great deal of worry. The signals could be made to travel over no more than forty-five feet; the current was too weak to go further. He wondered what he could do, and finally hit on a brilliant idea, born of sheer necessity. He called it the 'relay'—a device which was to become of fundamental importance in many branches of electric engineering. The relays were post stations in the old days of coach travel, where the tired horses were replaced by fresh ones. Morse translated this system into technical terms. The weak current arriving at the end of its range was required to do nothing but operate a tiny electro-magnet whose armature closed a fresh circuit powered by another battery. Thus the incoming signal was repeated over another length of wire. Theoretically, an endless succession of relays could carry the telegraphic signals over any distance!

It was this invention which helped him on. What he needed most of all was an associate with some mechanical skill, and money to build a good working model. Again he was near starvation, turning most of his pay into parts for the telegraph—without, however, making much progress with his model. In the end he split up his slender salary into daily allowances, rationing his meals which he cooked himself in his solitary bachelor's room.

He showed the ralay to one of his colleagues among the University professors, who in turn showed it to his students. Among them was Alfred Vail, the son of an ironworks owner. Vail was so enthusiastic about the idea that he knocked on Professor Morse's door and introduced himself.

'I don't want to be inquisitive, Professor, but—you are an artist, not a technician—what made you go in for these electrical things?'

'Well, I admit that I'm not an expert. But I have been working on an idea. . . . Come here, and have a look.'

Morse drew the curtain from a recess, and there was the electric easel. Vail looked at it from all sides. Then he said cautiously, 'Is this an instrument for transmitting signals from one point to another, Professor?'

'That's correct.'

'And does it work?'

Morse demonstrated the telegraph to Vail. The young man grew more and more excited. 'Professor,' he cried, 'you've got something great—something tremendous here on your old easel——'

Morse smiled sadly. 'So I thought when I started, five years ago. But I have come to realize that you need more than a good idea to present the world with new invention. You need technical skill and money. Both, my young friend, are things I do not possess.'

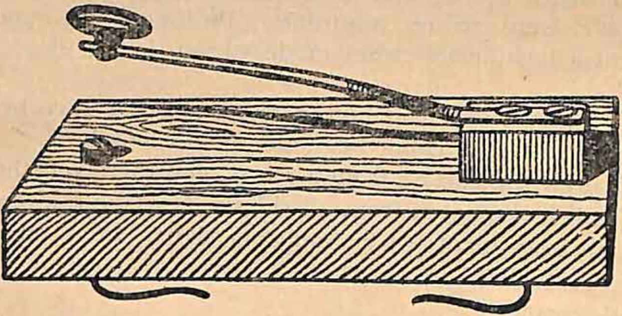
'I have some mechanical talent, Professor. Would you let me help you?'

'With pleasure. But——'

'I know. You haven't got the money. But my old man has. And plenty of it too! I'll eat my hat if I can't get him to sink a few thousand greenbacks in this electric telegraph of yours!'

The next day, Alfred Vail went to see his father in New Jersey. He returned with a cheque for a substantial amount. Then he rolled up his sleeves and set to work.

On 4 September 1837, Morse and Vail invited the whole University, professors and students, to witness the first full-scale experiment with the new model of the telegraph built by Vail. Wires were extended diagonally across the University Hall, and the apparatus—consisting of a 'key' for closing and opening the circuit, devised by Vail, and the electro-magnetic 'writer'—was set up in two corners linked by the wires.



11. *The Morse Key.* The first model of the dot-and-dash key, designed by Alfred Vail for Professor Morse.

Wondering what it was all about, the professors and students filed into the Hall. Morse explained briefly that they were about to witness the birth of a new instrument of communication, capable of transmitting messages with, literally, lightning speed. Vail then gave the audience some technical details. And as the audience formed little groups around the transmitter and receiver, Morse sent the first telegram by tapping the 'key'. It consisted of these words:

'SUCCESSFUL EXPERIMENT WITH TELEGRAPH
SEPTEMBER 04 1837'

—a message already showing the elements of a new language, the telegraphic style. At the other end of the line the pencil in the receiver scratched the signals on a moving paper strip.

The demonstration was a great success; but no one realized more clearly the shortcomings of the invention in its infancy than Morse and Vail. The code—it was an adaptation of the signalling alphabet used in the American Navy—was inadequate: too slow and complicated, and the slanting strokes of the pencil required too much power on the part of the electro-magnet. A simple, practical code—that was the first and most urgent need if the telegraph was to be offered to the world for general introduction.

AN ALPHABET FROM A NEWSPAPER

One evening, Morse was walking up and down his room, deep in thought, while Vail was tinkering with the electro-magnet. Suddenly, Morse stopped, and asked his young partner, 'Al, have you got a newspaper on you?'

'Only an old one, from my home town in New Jersey,' replied Vail. 'You won't find the latest news in it, I'm afraid.'

'I don't want the latest news. Here, put it on the table. Let's count the letters.'

'Count the letters?'

'Sure. I want to know which of them is the most frequent. And then the second-frequent, the third, and so on. I've got something in my mind.'

They began to count. The *e* turned out to be the most frequent letter. 'Good. Let's give it one dot in my new code. What comes next?' asked Morse. It was the *t*, and Morse gave it one dash. So they went on, going through the whole alphabet including the numbers and punctuation marks, allotting to each of them its special signal. Vail had no doubt that the Professor had hit the nail on the head again; this dot-and-dash code was simple, not too complicated to memorize, and technically easy to translate into the movements of the 'key' and of the armature in the receiver of the telegraph, for it required only short and long 'contacts'. It was exactly what the two inventors had wanted.

On 24 January 1838, they put up their new code, the Morse Code, on the blackboard of the New York City University. It has remained unchanged ever since, but its importance was increased immeasurably by the invention and introduction of wireless telegraphy around 1900.

With the creation of the new code, the time of struggle appeared to have come to an end, and Morse saw no reason why his invention should not have a clear run at last, with the whole world waiting for such an instrument. He wrote to the Federal Administration in Washington. An invitation to demonstrate the telegraph to the government and to Congress came by return.

Morse and Vail travelled to Washington, set up their apparatus, and sent their dot-and-dash signals along ten miles of wire. They came through distinctly and reliably. Everybody was enthusiastic, including van Buren, the President of the United States, who was present at the demonstration. Morse made many new friends, among them Mr Ellsworth, the Commissioner of Patents, and his pretty daughter, Annie. Although she was twenty-five years younger than Morse she seemed to be taking a great deal of interest not only in his invention but also in the inventor.

During the negotiations at Washington it was decided that Congress should be asked for an appropriation of thirty thousand dollars for the construction of the first telegraph line, from Washington to Baltimore. The Bill was to be introduced at the next session of Congress, and there was little doubt that the money would be granted.

What Morse did not know was that he had a powerful enemy in Washington; it was Johnson, the General Postmaster. This man feared that the telegraph would ruin the whole express mail system which he had built up—and which provided his friends with profitable jobs as postmasters. They were all, of course, against the new rival, the telegraph, and determined to frustrate any attempt to build an overland line, if necessary, by force. And these postmasters had the means of doing so, for they had at their disposal a great number of heavily armed postilions.

Morse, unaware of the danger, and impatient to introduce his invention all over the world, decided not to wait for the session of Congress, but sailed for Europe, confident that the success of the telegraph was assured.

A DESPERATE APPEAL

Morse had imagined that his European journey would be something like a triumphal tour. Instead, it was a road paved with disappointments. His first stop was England; here, patent rights were refused to him because two other inventors—of whom we shall hear more presently—had got in first with their version of the electric telegraph. In France, Morse was granted patent rights, but under conditions which rendered them practically worthless. The Austrian Emperor invited Morse to demonstrate the telegraph, said 'Very nice, very nice!'—and that was all. The Russian Chancellor singed a contract with Morse, but the Tsar, instead of ratifying it, tore it up. 'What's the use?' he said. 'As soon as I have these telegraph poles put up, my loyal subjects will pull them down—either because they want the timber or because they believe the devil's in those wires.'

Morse's only success on this European tour had nothing to do with the telegraph: it was his acquaintance with another great inventor, Daguerre, who showed the American his photographic camera. Morse took a set of equipment for making daguerreotypes back to New York, where he used it to take pictures on the roof of the city University building. Originally, the 'victim' had to sit in the sun for half an hour to have his portrait taken; but Morse improved the camera so that an exposure of ten seconds was sufficient.

Suddenly, Morse's whole edifice of hope collapsed. An economic crisis developed, the stock exchange panicked, hundreds of business men went bankrupt. Congress had other things to do than vote for an expenditure of thirty thousand dollars on such an unknown quantity as the electric telegraph. General Postmaster Johnson was busy among the Congressmen, stirring up opposition to Morse's scheme. Morse's friends failed him, and even Alfred Vail's father was unwilling to invest any more money in the telegraph; only Alfred remained faithful.

Morse submitted a new proposal to the Administration; but there came no reply from Washington. Months passed, lengthening into years. There was no discernible change in Morse's favour; his petitions and suggestions were either not answered at all or rejected straight away. Even Alfred advised him to stop worrying about the whole thing, and take up painting again.

Morse hesitated. Finally, in December 1842, he addressed a last, almost desperate appeal to Congress: 'If I cannot get a satisfactory reply I shall return to my brushes and have nothing more to do with the telegraph.'

This cry from the depths stirred the government to action. Congress responded by placing the 'Morse Bill' on its agenda—as the last item on the last day of session, 3 March 1843.

No inventor can ever have passed a day and night of such excitement as Morse did on 3 March. From the public gallery he followed the proceedings, trying to gauge the feelings of the House with regard to his Bill. Opposition seemed to be very strong; the General Postmaster's friends 'lobbied' all the Congressmen they could get hold of, and there were a good many who believed that the telegraph was not only a preposterous but a dangerous innovation. From time to time Morse's friends came up to the gallery to tell him what they knew. But they were unable to cheer him up. It looked as though the Bill was doomed. There would be no telegraph. . . .

It was past midnight when Mr Vail senior, himself a Member for New Jersey, told Morse that the debate on the Bill was shortly to begin, and that he would try to persuade his six fellow-Members to vote for it; there was a short interval in which he would talk to them. Then he hurried down to the lobby. Morse sat alone, terribly depressed. He felt that he was unable to bear the tension any longer, unable to watch the final defeat. He looked at the clock. There was just time to catch the night train back to New York.

In the jolting railway carriage he counted the money he had left after paying for his ticket. It was exactly 37½ cents.

He was eating his modest supper next evening when Annie Ellsworth burst into the room, straight from the Washington mail train. 'Congratulations, Professor!'

Morse thought the girl was making a poor joke. 'What do you mean?' he asked.

'Why, haven't you heard? You've won! The Bill was passed in the last five minutes—89 "Yeas" to 83 "Nays"! The six New Jersey Members did the trick!'

THE SALTHILL MURDER CASE

Work began at once on the first telegraph line linking Washington and Baltimore. A former mechanic and travelling salesman for patent ploughs, Ezra Cornell, promised Morse to get the necessary quantity of copper wire, which was difficult to obtain. He brought it along, and strung it himself from pole to pole, thirty-seven miles in all, within eight weeks. After completing the job he began organizing telegraph companies and putting up lines all over the United States; he became a millionaire, and established the famous University, which still bears his name, in his home town, Ithaca, N.Y., in 1865.

Johnson, however, showed his claws during the construction of the line, making Cornell's task extremely difficult. Wires were cut at night, poles pulled down, and workers complained that pot-shots had been aimed at them from behind bushes and trees. Cornell, Vail and Morse replied by organizing an enthusiastic group of young technicians, the future first telegraph operators, who put an end to Johnson's sabotage. Evidence of his activities was submitted to the President, who forced the General Postmaster to resign.

Everything was ready on 24 May 1844. Morse posted himself at the Washington telegraph, which had been installed in the hall of the Supreme Court in the Capitol, while Vail was waiting for the first message at the other end of the line, in Baltimore. It was Annie Ellsworth who tapped it out in the Morse Code; the message read, 'What hath God wrought!'

Oddly enough, the general public took little notice of the new world wonder. Morse realized that he had to wait for a lucky chance to show what his telegraph could do.

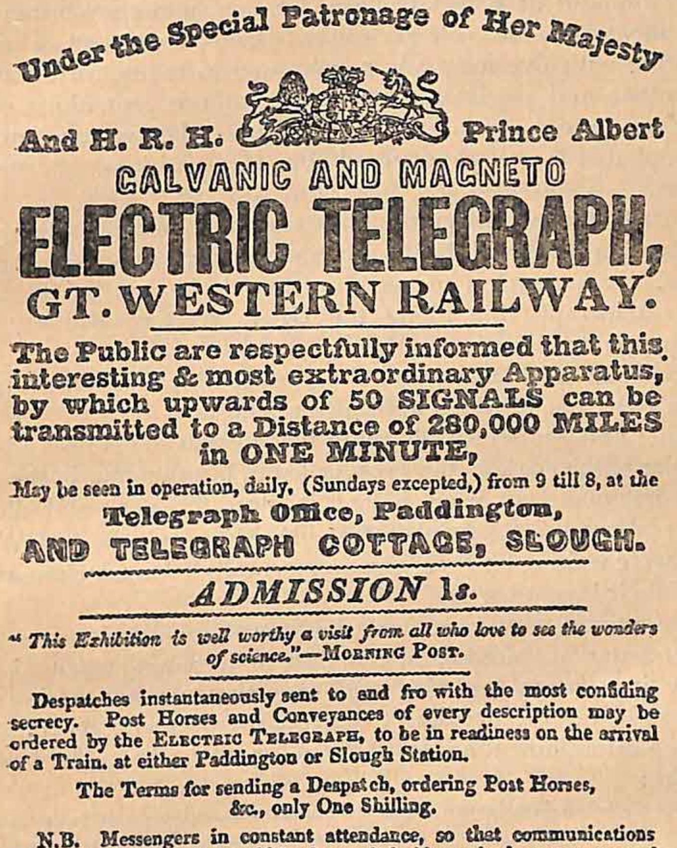
Only two days later, on 26 May, that opportunity presented itself. The Democratic Party held its National Convention at Baltimore to choose its candidates for the coming presidential elections. James Knox Polk, who was to become the eleventh President of the U.S.A., was nominated candidate for the Presidency, and Silas Wright as Vice-President. Vail sent the news at once to Washington, where Wright was attending Congress. Morse told him about his nomination; but Wright declared that he would not stand. Morse lost no time in sending the news to Baltimore. Vail took it immediately to the Convention, less than half an hour after Wright's nomination.

No one believed him, and he was almost thrown out as a swindler. A few hours later, however, the special courier of the Party arrived from Washington, confirming the sensational news. Within two minutes, the entire Convention was talking about one thing only—the miraculous telegraph; within an hour, Vail was swamped with messages for Washington; within two hours, Morse was snowed under with telegrams for Baltimore!

Twelve years of work, privation, and disappointment were at last beginning to bring their reward to the inventor, and soon every child in America knew the name of Sam Morse. Dot and dash had started on their conquest of the world.

In Europe, however, it took the Morse system a long time to get established. Like many other inventions, telegraphy had long been under investigation by English scientists. As far back as 1729, one Stephen Gray was said to have sent electric signals along a wire of 765 feet length, though with no idea of transmitting news. In 1745, Dr Watson, a Fellow of the Royal Society, used the water of the Thames for conveying electric signals from one bank to the other.

The first serious attempt at practical telegraphy was made by Sir Charles Wheatstone, who had started his career as an assistant in a London music shop before studying physics, and Sir William Fothergill Cooke, who studied medicine at Heidelberg, where he became interested in German attempts at solving the problem of



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Despatches instantaneously sent to and fro with the most confiding secrecy. Post Horses and Conveyances of every description may be ordered by the ELECTRIC TELEGRAPH, to be in readiness on the arrival of a Train. at either Paddington or Slough Station.

The Terms for sending a Despatch, ordering Post Horses, &c., only One Shilling.

N.B. Messengers in constant attendance, so that communications received by Telegraph, would be forwarded, if required, to any part of London, Windsor, Eton, &c.

THOMAS HOME, *Licensee.*

G. NURTON, Printer, 48, Church Street, Portman Market.

III. One of the posters displayed by the Great Western Railway Company in 1844.

telegraphy by electric means. Later, Cooke joined Wheatstone, then a professor at King's College, London, and they began their experiments in the college cellar. They developed a system operating with five magnetic needles and as many wires between transmitter and receiver: when a current was sent along one of the wires the corresponding needle moved. The various letters of the alphabet were represented by the positions of the five needles.

In 1838, the two inventors built their first telegraph line along the London-Blackwall Railway, using relays not unlike those of Morse. It was such a success that they decided to build an even longer telegraph line along the Great Western Railway from Paddington to Slough.

Londoners crowded around the posters which were put up one day in 1844, one of which appears on page 49.

Ladies and gentlemen of leisure made excursions to see the new 'wonder of science', as the Press called it, but the man-in-the-street could not make out what it had in store for him, and did not bother about the telegraph. Just like Morse, Cooke and Wheatstone were waiting for their great opportunity—for some sensational use of their invention.

That opportunity came on the morning of 1 January 1845. The operator at Paddington had just arrived and taken his seat at the instrument, yawning and expecting another boring day, when suddenly the needles of the receiver began to move. With growing astonishment and excitement, he jotted down the incoming message:

> a murder has just been committed at salthill and the suspected murderer was seen to take a first class ticket for london by the train which left slough at 7-42 am he is in the garb of a kwaker with a brown greatcoat on which reaches nearly down to his feet he is in the last compartment of the second first class carriage.

The telegraphist could not make out what was meant by the word 'kwaker', and sent a query back to Slough. He was told that 'kw' stood for 'the letter between *p* and *r*'—for there was no *q* on the panel of the telegraph. He rushed out to find the nearest policeman, and gave him the message.

When the train pulled into Paddington Station, two plain-clothes policemen were on the look-out for the 'kwaker.' The man alighted, unaware of the fact that the news of the black deed of which he was suspected had already travelled before him. He boarded a horse-drawn omnibus, followed by the detectives. They 'shadowed' him until they discovered where he was staying in London, and then quickly closed the trap.

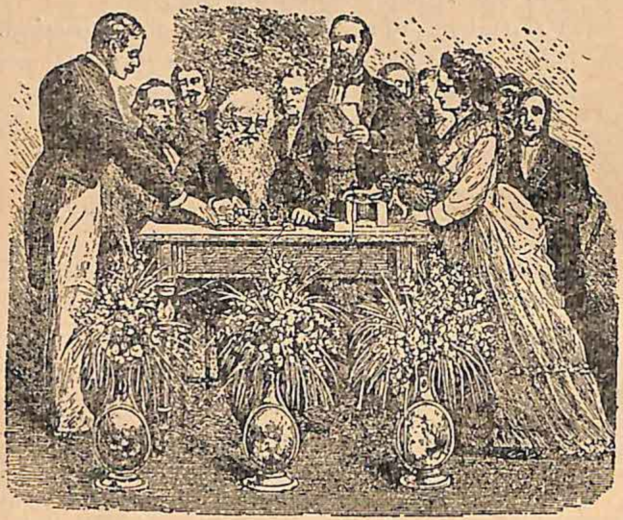
The murder trial of John Tawell aroused a sensation. Everybody discussed the telegraph and its enormous possibilities. Tawell confessed and was executed. 'Them cords,' said the Londoners, meaning the telegraph wires, 'them cords have hung John Tawell!'

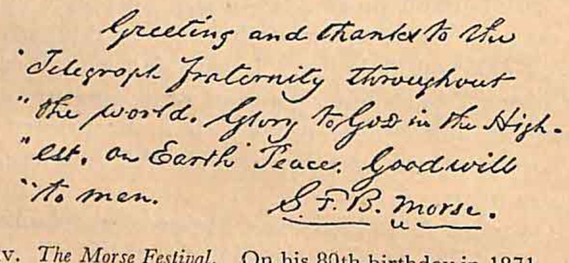
THE WORLD AT HIS FINGERTIPS

The Wheatstone-Cooke system of telegraphy survived in England for many decades, although the rest of the world adopted the Morse system exclusively within a dozen years after the opening of the first line. More and more possibilities of the new means of communication emerged. The first press telegram was tapped out in December 1846; it was the President's message on the conflict with Mexico. Five years later, the first submarine cable was laid between Dover and Calais. An international army of telegraph operators supplied the newspapers of all countries with reports about the world's happenings a few hours, and often only minutes, after the event. The dot-and-dash code established itself as a kind of supra-national alphabet. It was Vail who discovered, and convinced Morse, that most operators were interpreting the *sound* of the armature much more quickly than the printed signals on the paper band, and that the receivers should, therefore, be mainly acoustic instruments.

Morse re-married in 1847; it was, however, not Annie Ellsworth who became his wife, but a second cousin of his, who was nearer his own age.

His earlier disappointments in Europe were more than wiped out by a generous 'honorarium' of four hundred thousand francs —then about £25,000—which the French Foreign Minister, Count Walewski, sent him on behalf of a dozen European States which had adopted the Morse system. Money flowed into his pockets from every corner of the earth. It was a symbol of his undreamed-of success that the modest New York house where he had once tried to make ends meet by giving drawing lessons in an attic, made way for the magnificent Morse Building. Alfred Vail found a way of combining his telegraphic interests with those of his





Greeting and thanks to the
"Telegraph Fraternity throughout
"the world. Glory to God in the High-
"est, on Earth Peace, Goodwill
"to men. S. F. B. Morse.

IV. *The Morse Festival.* On his 80th birthday in 1871, Morse telegraphed this message—here reproduced in his hand-writing—to all American stations.

father's ironworks in New Jersey, but Morse himself retired to his little home at Poughkeepsie, N.Y., to take up painting again—the telegraph business had become so immense that it would only have confused him had he tried to take a hand in its commercial and industrial development. He was essentially an artist with no taste at all for business—which he left in the capable hands of Ezra Cornell.

There were, however, many legal actions in which he had to defend his patent rights. One of the claimants was Dr Jackson, whose unfortunate fondness for appealing to the law involved him in endless court cases: he claimed not only to have invented telegraphy but also to have discovered anæsthesia. He failed in both cases; Morse won easily against him after Captain Pell had given evidence that it was the artist who had made those mysterious remarks about 'a new world wonder, the electric telegraph' on board the *Sully*.

On Morse's desk at Poughkeepsie there was a telegraph key which enabled him to 'talk' to his friends all over the world, thousands of miles away, in the language he had created. The hammering and ticking of the dot-and-dash code had begun to change the face of the earth, for time and space had dwindled into fractions of seconds. On his 80th birthday in 1871, a great Morse Festival was held in New York, and his monument was unveiled in Central Park. Then the old inventor—now a venerable figure with a long white beard—sent the cable on page 52 to all telegraph stations from the Morse Building.

A year later he died, his finger still on the telegraph key which had opened the door to a new age of communication among men.

3. *THE FATHER OF THE SKYSCRAPER*

HENRY BESSEMER AND THE AGE OF STEEL

RAILWAY lines and razor blades, ships and tanks, pocket knives and skyscrapers—these things, and thousands more, owe their existence to steel. The farmer, the motorist, the builder, the engineer—they couldn't do without it. We have been told that the Atomic Age has begun. Has it really? The basic material of our time is steel; we are still living in the Steel Age. In fact, it began only recently—about a hundred years ago.

If you had asked the man-in-the-street of a century ago what part steel played in his daily life he would have shrugged his shoulders.

'Oh, steel? Well, it doesn't play a great part at all.... Too expensive, you know. Imagine, it costs £50 a ton, or even more! what are we using it for? Now let us see. Tools, cutting tools, of course....and table knives. What else? No, I'm sorry, can't think off-hand of any other use for steel.'

'But what about railway lines?' you may have asked.

'Oh, no, they aren't made of steel. The railway companies would all go bankrupt if they had to use that expensive material! They make the lines of ordinary wrought iron. That'll have to do for the time being. Of course, if trains became faster and heavier—those wrought-iron lines couldn't stand up to it....'

The Age of Steel had not begun then.

It was an Englishman who opened the gate to that epoch in the history of mankind. His name was Henry Bessemer. A strange name; in fact, the Bessemers had come to England from France, as refugees from religious persecution. Their name was originally 'Basse-Mer,' and they were Huguenots. In the eighteenth century, however, Anthony Bessemer, Henry's father, returned from England to the Continent. He was only twenty when he helped to instal the first steam pump in Holland; it drained the turf pits at Haarlem. From Holland, Anthony Bessemer went to Paris, which seemed safe enough for a Huguenot then. He got a job as designer at the Royal Mint, but when the Revolution broke out he lost it, and the Bessemer family returned to England, exiled for the second time. Anthony settled in Charlton, a country village some thirty miles north of London. It was here that Henry Bessemer was born in 1813.

A PACKET OF FORGED STAMPS

There was nothing that interested the boy more than machinery. The family had set up a type foundry, which had a great fascination for Henry. Strictly against the rules, he would hide in the foundry to watch the operation of the melting furnace. One day, however, his father discovered him, because something got into the boy's nose and he couldn't help sneezing—it was the powdered antimony used in the process.

Then again, he would sit for hours near the water mill at the other end of the village, watching the old wooden wheel go round, and as a result he would be late for dinner

'After leaving School I begged my father to let me learn something of practical engineering,' Henry Bessemer wrote in his autobiography, which is a fascinating Victorian success story. 'I was very fond of machinery, and of watching it when in motion. ....In 1830, when I was 17, we moved from Charlton in Hertfordshire to London. A new world seemed open to me. The metropolis, with its thousands of vehicles and pedestrians, its gorgeous shops and stately buildings, and its endless miles of streets and numerous squares, overwhelmed me with wonder and astonishment. And yet, there was one thing strange to me, and sadly wanting. I felt that I was alone; no one knew me. How often I thought, "Shall I ever be known here? Should I not strive to make a name for myself, even in this mighty London?" I knew full well that I laboured under the great disadvantage of not having been brought up to any regular trade or profession.'

This feeling of loneliness, and even that of being inferior to other young men in regular professions, was one of the mainsprings which operated the mighty ambition stirring in the young man. And so he set out to conquer London.

His first adventure, however, nearly put an end to his career before it even began. Henry had decided to invent things, and to keep his ear to the ground for all kinds of ideas that might be of use to the public or the authorities. So he noticed how easy it would have been for an unscrupulous man to forge the Government stamps used on legal documents. He read that there was an annual loss of thousands of pounds, sometimes even £100,000, through the illegal practice of using those stamps twice or more times by detaching them from old documents and fixing them onto new ones!

This was his cue for the first invention he ever made—a perforated die which cancelled the stamps according to date. He wrote to the President of the Stamp Office telling him about his invention; and his satisfaction and excitement were great when he received a letter asking him to demonstrate his device to the President on a certain day. He thought it might be a good idea to prove to the President how easy it was to forge Government stamps; so he made some stamps himself, and put them in a packet which he intended to take along to the interview.

One fine morning in 1833, he set out along Fleet Street towards Somerset House, where he was to meet the President, carrying the packet with the forged stamps. On his way he saw some oranges at a greengrocer's stall, and bought one. Eating it while continuing on his way and submerged in his thoughts about the importance of the interview, he did not notice that he had left the packet at the greengrocer's. His thoughts became even more blissful when he slipped into a day-dream about the girl he loved—the girl he would marry if he was able to sell his first invention——

Suddenly he woke from his dream with a start. The parcel had gone, the packet with the forged stamps! Cold sweat appeared on his forehead as he turned and hastened back: if—someone had opened that parcel to see who was the owner, and found a bunch of forged stamps in it—together with Henry's name and address—the inventor would find himself in jail sooner than before the altar. No wedding bells for poor Henry....

He arrived at the stall completely out of breath. Thank Heavens, there was the packet on a shelf; it had been put aside, for the greengrocer was sure the forgetful young man would come back for it. With a sigh of relief, Henry put the stamp parcel in his pocket.

The interview went well. The President had already tried out the die, which the inventor had sent a day or two ahead of his visit. The forged stamps made a great impression on the President, and the invention was adopted.

Young Bessemer's first invention, however, never made any money for him, although the Stamp Office saved up to £100,000 per year through the use of his perforated dies. 'But I was nevertheless pushed from pillar to post, and denied all remuneration for the important services I had rendered,' he wrote in his autobiography half a century later. 'I was too busy making my way in life at this period to press any legal claims against the Government. I had no friend at Court, and had to bear this shameful treatment as best I could.'

The last straw was the Government's refusal to let him accept, forty-five years later, the French Grand Cross of the Legion of Honour, offered to him in appreciation of the great achievements which had, by that time, made his name world-famous. His indignation was so much aroused that he wrote to the Prime Minister, Lord Beaconsfield, recalling the story of the perforated dies, and of the unworthy treatment he had received by his own Government as far back as 1833, at the age of twenty. Lord Beaconsfield's answer was that he had submitted Bessemer's name to the Queen—and Bessemer was knighted as a long-delayed reward for his services.

The immediate effect of the young man's interview with the President of the Stamp Office was that he did not hesitate any longer to ask the girl he loved to marry him; she accepted gladly.

TULIPS, BRONZE POWDER, AND HEAVY GUNS

At twenty, Henry Bessemer was already a successful inventor. Now he had the courage to take up all sorts of new schemes and ideas: improved methods of making pencils from black lead, of crushing sugar cane, of embossing Utrecht velvet. And then came the invention which started with his father's beloved tulips....

'At Charlton my father grew his tulips, and my sister used to paint all the finest specimens he produced,' Henry Bessemer tells us. 'I remember going to the shop of a colourman in Clerkenwell, to get some bronze powder to do ornamental writing on her portfolio of flowers. I was greatly astonished to find that I had to pay seven shillings per ounce! I could not help asking myself, "How can this simple metallic powder cost so much money? It must be made slowly and laboriously by some old-fashioned hand-process.... A splendid opportunity for any mechanic who can devise a machine capable of producing it simply by power." How trivial and unimportant this incident must appear! But it changed the whole current of my life.'

While his sister wrote the words *Studies of Flowers by Miss Bessemer* in bronze powder at seven shillings per ounce on the cover of her portfolio, Henry went to work on his new idea. But he found that the task was far from easy. He experimented for weeks and months, and in the end it took him years to build a machine which produced bronze powder mechanically with only one-twentieth of the labour formerly required.

The traditional, expensive method had been to beat copper alloys into thin leaves, and then to grind them to powder by hand on marble slabs. Bessemer designed his machine, to be powered by a steam-engine, in the form of a lathe working at very high speed, which scraped off 2,000-3,000 fine filaments per minute from a solid brass lump; these filaments were then rolled into thin sheets and broken up into powder under great mechanical pressure; finally, the powder was made even finer by letting it drop from a height of 5-6 feet onto a bronze slab in a continuous stream.

With that machine there began an entirely new branch of industry—British-made bronze powder. It was not a big industry by modern standards, but it would in itself have been sufficient to make Henry Bessemer a rich man; for forty years it secured him a steady, substantial income. The bronze powder, which had decorated devotional addresses in China as far back as Confucius's time, was now mass-produced in London in sealed machines working in carefully-locked rooms: for in those days the patent laws were not sufficient to safeguard an inventor entirely against 'piracy'.

However, being an inventor by talent and inclination, Bessemer just couldn't stop inventing. He tried his hand at type-setting machines, optical glass, and railway brakes; none of these were as successful as the bronze powder machine. Then the Crimean War broke out, giving his thoughts a more martial turn. In those days, heavy guns were unable to shoot with anything but enormous balls, and were very inaccurate. Bessemer believed that rotating projectiles could greatly improve the accuracy of aim.

'I submitted my plans to the War Office,' he records in his life story. 'Yet with the tendency of our military authorities to pooh-pooh every proposition of the civil engineer, my scheme was set aside and so simple an experiment as the manufacture of half a dozen projectiles was refused. I, however, was determined to ascertain for myself whether I was right or wrong!'

This he did in a most original way—by turning his own back garden into an artillery range. He made a simple cast-iron gun and half a dozen small-scale projectiles, with grooves to make them rotate. By using small charges he made the shots fall within his own grounds at Highgate, where he was then living. He was very pleased with the results.

A few months later he happened to go to Paris on a business trip, and was invited to a farewell dinner given to a number of French officers who were going to the Crimea. The Emperor, Napoleon III, was the guest of honour, and Bessemer was introduced to him. He was quick in grasping this unique opportunity to tell the French monarch about his experiments with rotating shots. Napoleon listened with great interest.

'You are an Englishman, Monsieur Bessemer,' he said, 'but we are all together in this war. So I wonder if you would mind showing our French experts your invention? I shall give you all the necessary facilities for experiments on a large scale.'

Bessemer agreed, and within a few weeks the projectiles for the heavy French guns were ready. He took them to Vincennes, the French artillery centre, where the trials were to be held. Everything went according to plan, and the French officers who supervised the tests seemed to be very pleased. By the time the experiments were finished the winter sun was setting; Bessemer and the Frenchmen, weary and cold, returned to the officers' mess. By the warmth of a cosy fire and the gentle glow of steaming cups of mulled wine the day's results were discussed.

'I am glad that I can report the full success of your projectiles to His Majesty,' said the Commanding Officer to the inventor. 'Your projectiles revolve with sufficient speed, and never fail to hit the target, point forward. Very satisfactory indeed! I only wish our guns were as good as your shot.'

'Yes, I think that's the real problem,' remarked one of the military engineers. 'The guns are not strong enough. I shouldn't have been surprised if one of the barrels had burst!'

'Do you think, Monsieur Bessemer, that guns could be made to stand up to such heavy projectiles without wearing out after a few dozen shots?' asked the Commanding Officer.

'Well,' replied Bessemer, 'I don't see why that should be impossible.'

'Then why don't you make them, Monsieur Bessemer?'

'COLD AIR TO MAKE IT HOT'

A stronger gun . . . why not?

The thought went round and round his head as he travelled back to Paris in that cold December night. It was all a question of producing better iron, fit for the job. 'At that moment, I had no idea whatever in which way I could attack this problem,' says Bessemer in his reminiscences, 'but the mere fact that there was something to discover was sufficient to spur me on. It was like the first cry of the hounds in the hunting field. It was a clear run that I had before me—a fortune and a name to win!'

Before the year was out he found himself already busy with plans, and within three weeks after the Vincennes trials he applied for a patent for 'Improvements in the Manufacture of Iron and Steel'.

Steel—that was the solution. But only in theory; because there was still no steel suitable for structural purposes. Ships and bridges and axles were made of wrought iron, and the use of steel was confined to small objects because it was so expensive. That steel was made by the so-called 'blister' process from wrought iron imported from Sweden at £15 a ton: the iron bars were packed in stone boxes filled with charcoal; there they were heated for several days, during which time the carbon was partly transferred from the coal to the iron. When diffusing the iron, the carbon met slag particles, which are always present in wrought iron, and formed carbonic oxide. This gas, unable to escape, would puff up the molten metal into blisters—thus accounting for the name of the process. Finally, the bars were broken into small pieces, and melted in crucibles holding not more than 60 lb. each. This process was long and costly, and such steel was sold at £50 to £60 per ton. The bars of wrought iron from which the steel was made were produced from pig-iron by 'puddling'—stirring the molten iron by hand. Puddling demanded great strength, endurance, and skill.

Like so many great inventions, the one that made Bessemer famous was brought about more or less by chance. He began to experiment with pig-iron, trying to find a more economical method of turning it into wrought iron than by puddling, as the Swedes did it. When Bessemer melted his pig-iron he observed that some pieces, which happened to be exposed to an air draught, remained unmelted in spite of the great heat. After cooling, he examined these pieces and found that they were shells of wholly decarbonized iron, the carbon of which had been burnt out by the air draught alone!

This gave him the great idea of making steel without fuel.

But how was he to achieve this aim? He wanted to convert crude, cheap pig-iron into malleable iron while it was still in a fluid state, and to retain the metal in such a state long enough for it to be cast in moulds, without using any fuel at all in the process. Instead, he wanted to force a large number of fine streams of air through the metal, causing the oxydization of its impurities such as carbon, silicon, phosphorus, sulphur, and so on. The intense heat thus created would raise the temperature of the metal above the melting-point of steel, which is 1500 degrees centigrade.

For this process he designed what is now known as the 'Bessemer Converter', an immense retort made of boiler plates, lined with fire-bricks, suspended aloft and mounted on an axis near its centre of gravity so that it could be easily tipped.

The first large-scale experiment was the most thrilling experience in Bessemer's life. He had engaged an iron-founder's furnace attendant to manage the melting of the charge—the first stage of the experiment.

'I want you to run the metal by gutter into that converter,' he told the man.

'You mean that little furnace from which I have just raked out all the fuel?'

'Exactly. And then I shall blow cold air through it to make it hot.'

'Cold air .... to make it hot?' The man's suspicion about the mental health of his master was to be read in his face. Then he shrugged his shoulders; after all, he was being paid for the job.

'Now look; you pull this lever here.... That's it. This blows jets of air through the molten iron. It works like this: first, the silicon in the iron is attacked by the oxygen from the air. There's up to two per cent of silicon in the iron. Then the oxygen attacks the carbon, of which there's about three per cent in it. .... Careful now—stand back!'

A noise of furious combustion made the man almost run for his life. 'God help us, master!' he cried. 'It's going to burst!'

Bessemer calmed him down. 'No fear. That's the burning carbon. Those openings in the converter are provided for precisely that rush of flame. .... Now the carbon's burnt out, you see?' The noise had stopped all of a sudden. 'Go ahead, tip the converter!'

A stream of molten iron flowed into the mould.

'It is impossible to convey any adequate idea of my feelings when I saw this incandescent mass rise slowly from the mould,' wrote Bessemer. 'The first large prism of cast malleable iron ever made! This was no mere laboratory experiment. In one compact mass we had as much metal as could be produced by two puddlers and their two assistants with an expenditure of much fuel. We had obtained a pure homogeneous ingot as the result of thirty minutes' blowing, wholly without the use of additional fuel or skilled labour. No wonder, then, that I gazed with delight on the first-born of the many thousands of ingots that now come into existence every day. . . .

'I had now incontrovertible evidence that in the space of half an hour molten pig-iron could be raised to a temperature previously unknown without the employment of any combustible matter except that which it contained. At the same time it was deprived of its carbon and silicon, wholly without manipulation. What all this meant, what a perfect revolution it threatened in every iron-making district in the world, was obvious as I gazed on that glowing ingot!'

MR BUDD HAD SOME FUN

Within five years, Bessemer—who was a good business man as well as a brilliant inventor—took out no fewer than 114 patents to safeguard his process. But the industry was extremely sceptical about this new-fangled idea of making first-class steel from pig-iron at £3 a ton, instead of using Swedish wrought iron at £15, within thirty minutes instead of six days, and without additional fuel! The British Association invited Bessemer to read a paper on his process during their meeting at Cheltenham in 1856, but the manufacturers, engineers, and business men who gathered there did not expect to hear anything of a revolutionary nature from Bessemer.

He was just having breakfast in his hotel with Mr Clay, a Liverpool foundry manager, when Mr Budd, a Welsh iron-maker, came up to the table.

'Hello, Clay! I want you to come with me into one of the sections this morning. We're going to have some fun,' said Mr Budd.

'Sorry, Budd, I'd come with pleasure, but I'm specially engaged this morning—with my friend here.'

'Never mind, Clay,' replied Mr Budd, casting a brief glance at Bessemer, whom he did not know. 'You must come along. D'you know there's actually a fellow come down from London to talk on the manufacture of malleable iron without fuel? Ha, ha!'

'Well, as a matter of fact that's just where this gentleman and I are going,' smiled Mr Clay, while Bessemer ate his toast without as much as batting an eyelid. 'I'm glad you'll be there, Budd. I guarantee you're going to have some fun!'

When Mr Bessemer mounted the dais, the Welshman in the hall felt rather uncomfortable. But when the speaker had finished, Mr Budd was one of the first to rise to take part in the discussion.

'I have listened with deep interest to the account of his invention,' he said, 'and I want to tell Mr Bessemer that if he wants an opportunity of testing his method on a grand scale I shall be most happy to put my entire works at his disposal—and it will not cost him a penny!'

However, Bessemer preferred to elaborate the new process in his own workshop. There was one particularly tricky problem to be solved. Several steel manufacturers, who tried his method, used British pig-iron—and failed. The reason was that it contained too much phosphorus, and Bessemer was unable to dislodge that 'fatal enemy', as he called it.

'The large fortune that had seemed almost within my grasp was now far off,' he recalls. 'My name as an engineer and inventor was at stake. It was, indeed, a hard struggle. I was paralysed for the moment in the face of the stolid incredulity of all iron and steel manufacturers. So I made up my mind to adopt the only means open to me—namely the establishment of a steel works of my own in the great steel industry of Sheffield.

'During the time that the works at Sheffield were being erected I was very busy endeavouring to discover all the non-phosphoric iron ores in the country, and after many analyses, the chief were found to be the lematites of Lancashire and Cumberland.'

At last Bessemer got his factory going. But the War Office and the Admiralty would not be convinced; they said that Bessemer's steel was 'treacherous'—until the French used it and built two warships with it! Their lead was followed everywhere. Bessemer steel had come to stay, conquering the whole world and the Seven Seas. Altogether, the inventor received about one million pounds as patent royalties for his process during his lifetime.

THE SHIP WITH THE SWINGING SALOON

One day in 1885 a crowd of people gathered in a Chicago street for the inauguration of a very strange building—in fact, a modern miracle: it was a house twelve storeys high, the first of its kind. The poeple of Chicago had watched it growing taller and taller, and someone called it 'skyscraper'. The name stuck.

After the short ceremony everybody crowded around the architect. 'Say, how d'you manage to keep that enormous thing upright?' they wanted to know.

'Well, there's no black magic about it. It's what we call a skeleton construction. Just an ordinary iron framework up to the fifth floor——'

'And above the fifth floor?'

'Well, at the suggestion of the Carnegie Steel Company we've used those new steel beams they're now making .... rolled steel beams made after the Bessemer process, if you've heard the name.'

'Bessemer—sure, one of our great American inventors!'

'You're wrong there, sir. He's an Englishman. There are still some good brains in the old country. Perhaps that fellow Bessemer will go down into history as the father of the American skyscrapers.'

'Skyscrapers? So you're going to build more high houses like that?'

'Why not? And even higher ones. May be in New York, too.'

And sure enough, during the years that followed, skyscrapers shot up in America's cities like mushrooms after the rain, and Manhattan's skyline took on that familiar yet fascinating shape which greets the visitor on his arrival from Europe. Bessemer had indeed become the father of the skyscraper, as well as the father of the Age of Steel. Thanks to his process, steel production in Britain alone has risen from less than fifty thousand tons a year to nearly twenty million tons during the last century, while the price fell from £50-60 a ton to one-fifth or a quarter of that sum.

Many inventors would have been content to sit back and reap the enormous benefit of their achievement in idleness. Not so Bessemer. To the end of his days—he died, over 85 years old, in 1898—he experimented with a whole range of things and ideas. Now it was a new mirror-grinding machine, now asphalt pavement; a 'solar furnace' for utilizing the heat of the sun, or a new type of Channel steamer that prevented sea-sickness. This, in fact, was his pet idea. Bessemer hated the Channel crossing, and so he invented a ship with a swinging saloon that was supposed to stay in the horizontal, however much the hull of the ship was rocking and rolling. The ship was actually built and created a sensation; unfortunately, it did not work, and those on board got more sea-sick than ever. This was a disappointment that angered him so much that even being knighted by Queen Victoria, and having thirteen American towns named after him did not give him the pleasure they would otherwise have done.

In his eighties he was still upright, six feet tall, with keen eyes and impressive side-whiskers, a typical Victorian gentleman and family father with his stiff 'choker' collar and black bow-tie. In his luxurious over-decorated villa in Denmark Hill, south of London, he would go about with a Turkish smoking-cap, making his daily round from the observatory to the underground grotto (in the style of the Alhambra), or visiting his Shetland ponies and prize cows: the personification of success, a man typical of his time, yet towering head and shoulders above his contemporaries. He had come a long way since the day he walked up Fleet Street, clutching his little packet of forged stamps.

4. *STICKY STUFF, THAT RUBBER*

CHARLES GOODYEAR AND THE DISCOVERY OF VULCANIZATION

SPOONS and clocks, pitchforks and buttons—there was no article of everyday life that Mr Amasa Goodyear left alone without trying to improve it. He was a born inventor in an age which held out ample hope of wealth and fame to the man-with-a-bright-idea, in America more than anywhere else. The time was the early nineteenth century, and the place New Haven, Connecticut. Mr Goodyear's little house bristled with new and unfamiliar things, all of them inventions of his own—for his mind and fingers knew no rest; and when the little American Army had to fight the war of 1812 against the British it wore uniform buttons invented and made by Amasa Goodyear.

When his son Charles was 16 he was a slender lad whose health was not too robust, and who wanted to become a minister of religion. He was not interested in business and money-making. But his father would have none of it; he needed the boy to help him in his small factory in nearby Naugautuk. Thus began Charles Goodyear's own career as an inventor. He was no less headstrong than his father, but with an added zest and fanaticism which one could call religious—and which was bound to get him into trouble.

For some years, father and son worked together, Amasa inventing and producing things and Charles selling them. At the age of 26, Charles had the idea of establishing a hardware shop in New Haven, the first in the United States; until then, hardware merchants walked from place to place carrying their goods in a pack on their shoulders, or travelling in horse-drawn wagons across the country. Goodyear's example was soon copied all over America. The shop did brisk business, and the family—including Charles's wife, Clarissa, and their children—seemed to be heading for a really prosperous future.

But Charles Goodyear the shopkeeper was hardly a typical business man: when money matters had to be discussed he would yawn and think of different things. It was the thrill of producing, inventing, discovering which exerted its spell over Goodyear as long as he lived, and he regarded his shop merely as a means of distributing his products to his fellow-men so that they would benefit from them. They liked him as a salesman: tall, slim, handsome, polite, and with a clear, soft voice, Charles Goodyear seemed bound to get on well in the world.

Then, suddenly, bad luck began to cast its shadow on his happiness. He fell ill and had to stay in bed for a few months. When he returned to the shop he found that an economic crisis had developed, and many customers were unable to pay. Charles Goodyear, to whom money meant little, did not press his debtors—with the result that the store could not pay its own debts. Within a short while, everything he had built up crumbled to dust around him. In order to save his father from trouble, he took full personal responsibility for the debts of the firm. The cruel custom of putting a man in jail if he could not pay his debts was still in force; and so Charles Goodyear, 30 years old and a father of five children, was sent to prison for the first time in 1830.

When he was released after a few weeks he tried to do business in other towns—which also had prisons; within four years he saw the inside of half a dozen of them, each time for no offence other than that of incurring debts he was unable to pay because of the crisis. If he could only make some great discovery! Was not America the land of unlimited possibilities? And he began to have a good look round for some hint or cue.

BURST OF THE RUBBER BUBBLE

One morning in 1834, Charles Goodyear walked through the streets of Boston and looked at the shop-windows. Suddenly he stopped. The window which attracted his interest belonged to the Roxbury India Rubber Company. 'Rubberized Clothing' said a placard, and the display showed some coats, a pair of shoes, and a 'life-preserver'—a canvas jacket with rubber lining, which could be inflated so that it would keep its wearer from drowning. It was the last which set his inventive mind to work. After a few minutes, he entered the office of the company and asked for the director, Mr Chaffee.

'Are you interested in a new idea which would improve your life-jackets?' he asked.

'Well, why not! Let's hear.'

'I think I could improve on that inflation tube.'

'You could? All right, there's no harm in trying. We know it's not perfect. See what you can do.'

A few days later he was back with an inflation tube of a more efficient design, and sold it to the company. 'And I've got some more ideas,' he said. 'This stuff, this rubber, interests me.'

'Then go ahead,' said Mr Chaffee. 'We're always willing to buy.'

They did not have to wait long before he appeared again, with a portfolio full of drawings and specifications. He pounced on Mr Chaffee to explain his ideas to him enthusiastically, but was beckoned into the private office; and before he could start, he learned of a new development that made his heart sink. The rubber industry was on the rocks.

The story of rubber as an industrial raw material was short and dramatic, although Europeans had seen this material much earlier. Christopher Columbus and his men watched the American natives play with balls that bounced better and were much lighter than those made in the Old World, but they took little notice, for they were looking for gold. The South American Indians called the tree from which this sticky substance oozed out 'caoutchouk', 'the weeping wood', and they made the stuff solid by turning it slowly on a stick over a smoky fire. They made shoes and even elastic bottles from it. A Spanish general and gold-seeking adventurer, Torquemada, reported that his men used it in America 'to wax their cloaks against the rain'. It was brought to Europe, and scientists and inventors began to struggle with the curious substance. The English scientist, Joseph Priestley, described that caoutchouk was 'a substance excellently adapted to the purpose of wiping from paper the marks of a black lead pencil'—and named it 'rubber'. Samuel Peal, another Englishman, discovered a rough-and-ready method of rubberizing cloth in 1791.

Slowly it was recognized that rubber possessed many useful qualities: it was highly resilient, and it could protect a piece of garment from water—the Scots inventor, Macintosh, developed a waterproofing process in 1823. But—and this was decisive—rubber was unable to stand up to hot weather; it melted and 'ran', and the smell it developed was not exactly pleasant. In very cold weather, it became brittle and cracked.

America's rubber industry started with the invention of a machine for spreading dissolved rubber on cloth, made by Chaffee in 1831. He founded the Roxbury India Rubber Company in Massachusetts, which was very successful in selling its waterproof clothing, and soon increased its capital to $600,000. Other companies started in half a dozen towns, like mushrooms after the rain; it was a race to beat the other rivals as long as the going was good. For no one in the new industry had any illusions about the dreadful things that would happen in the first heat wave!

That heat wave came while Charles Goodyear was working out his ideas in Boston. And Mr Chaffee had to tell him that the company was heading for bankruptcy: rubber goods they had sold were being returned by the car-load; others had 'run away' in the warehouse; and some £20,000 worth of goods had been hauled out secretly at night and buried in a lonely place. Other companies were, of course, caught in the same way; the people who had invested their money trustingly in the rubber industry were going to lose some two million dollars!

LABORATORY IN THE PRISON CELL

Charles Goodyear left the Roxbury office like a man in a dream, hoping for something to wake him from that nightmare. But worse was still to come. They were waiting for him when he returned to his lodgings. A creditor had caught up with him. Back he went to prison.

It was characteristic of Charles Goodyear that this time he did not mind the disgrace and discomfort of being behind bars. For now he had something to think about: how to turn rubber into a stable material that would stand up to temperature changes. But why only think? He asked to see the prison superintendent.

Never before had a prisoner made such a strange request.

Goodyear asked to be allowed to turn his cell into a chemical laboratory! He wanted permission to have a marble slab, a rolling pin, a big lump of rubber, and as many chemicals as his wife could afford to buy sent to his cell. The superintendent agreed.

A gaol cell was as good a laboratory as any; better, for there were no creditors who could disturb him, and no scramble for the daily meal. It was here that he made his first important discovery: that the stickiness could be removed from the surface of the raw rubber by mixing it with magnesium.

That was as far as he got. He tested one rubber compound after the other, kneading them with his fingers, rolling them on the slab. Magnesium was the only material that had the desired effect on the surface. As soon as he was free he returned to New Haven, and began to produce shoes from rubber mixed with magnesium, at first on a very small scale, in the kitchen of his house. They were a success, and orders flowed in. All the family and three or four hired girl workers helped; and they all lived in the comfortable old Colonial house he had rented. The money Goodyear earned was invested in further experiments; for the magnesium process could be applied only where rubber was to be used as a thin skin. It cured only the surface. The real secret of making rubber a useful material still eluded him.

'I was encouraged in my efforts,' he wrote, 'by the reflection that what is hidden and unknown, and cannot be discovered by scientific research, will most likely be discovered by accident, if at all, and by the man who applies himself most perseveringly to the subject and is most observing of everything related thereto.'

The factory in the old house came to an abrupt end when the neighbours complained about the odour. He had to get out. He sold his furniture and his wife's household linen, put the family in a boarding-house, and went to New York in the hope of raising some money to get on with his work. He had found that quicklime and water would also give a dry surface without stickiness, and could be adapted to sheets, toys, and clothing. He showed an exhibit at the Mechanics Institute in New York, won a few medals and awards, attracted public attention, and met people who did not seem unwilling to finance a factory. One day, however, he happened to drop some acid on a piece of rubberized sheeting. It made the rubber as sticky as before!

AN UMBRELLA FOR A FERRY TICKET

Many an inventor would have been dismayed by this setback. Not so Goodyear; now he was more than ever determined to find the great rubber secret. Broke, but optimistic, he took a room in Greenwich village, New York's 'Bohemian' suburb, and looked for some lonely spot where he could carry out his experiments without insulting anyone's nose. He found an unused mill, five miles from his lodgings; and he walked these five miles, each way daily, carrying a gallon jug of chemicals on his back, to continue his experiments. He had no money for elaborate equipment: his principal tools were determination and belief in the future of rubber.

It was here that he discovered, in 1837, that nitric acid would protect rubber from the effects of heat. He found this out half by experiment and half by accident. Goodyear was fond of colours and decorations, and the rubber goods he made for sale all had a little extra something to make them attractive. One day, while working with bronze solution, a few spots of the stuff splashed on some decorated rubber goods. Instinctively, he reached for the nearest bottle to rub off the spots. It happened to be an aqua-fortis, nitric acid. Later that day, he heated the rubber goods again, and found to his joy that those treated with nitric acid could stand much more heat. What he did not know was that the active ingredient of the aqua-fortis was an impurity in the acid—sulphur. For it is manufactured by the action of sulphuric acid, and some sulphur usually remained in the aqua-fortis in the old days of imperfect chemical processing.

If he had only known then how near he was to the solution of his problem! But he did not suspect yet that it was the sulphur in the aqua-fortis which made the rubber more heat-resisting. Instead of continuing his experiments systematically he went into production again, rubberizing dozens of articles from cloth bandages to maps. He sent letters printed on rubber to the President of the United States, Andrew Jackson, and to a number of senators.

He took out a patent and found a financial backer, Mr William Ballard, who rented a sales office for Goodyear's wares in New York City and a factory and warehouse in Staten Island. Production of shoes, life-jackets, and clothes began on a grand scale. Goodyear thought he could at last see the clouds of misfortune breaking. He moved his wife and children to Staten Island near the factory. All seemed to be well.

Just then, however, a new economic crisis descended over America. The panic caught Mr Ballard. Factory and office had to be closed. Goodyear searched in desperation for a new backer; but nobody had enough money. Within a few weeks, the family was penniless: the children went fishing for food in the bay. They tried to make a few cents by sewing aprons, piano covers, and the like by hand, peddling them around in the neighbourhood, and Mrs Goodyear made bonnets out of pasteboard. But Charles Goodyear himself continued to believe in rubber. All over New York, people knew him as a rubber monomaniac. 'If you see a fellow wearing a rubber coat, a rubber cap, rubber shoes, and a rubber purse with not a cent in it—that's Charlie Goodyear!' they said.

He borrowed money where he could and pawned the last of his silverware. Once he boarded the ferry steamboat to New York City on his way to a pawnshop. When the ticket-collector came along he said, 'Look here, I've got no money. Can you take me along, and I'll pay you on my way back?'

The ticket-collector looked at him sternly. 'You'll have to see the Captain about that,' he said. 'Come along!'

The Captain listened gravely to Goodyear's tale of woe. 'If I let you off I'll have my boat full of non-paying passengers in a short while, and have to get out of business,' he said. 'Haven't you got anything you could leave me as a security?'

Goodyear had a bright idea. 'What about my umbrella? It's fine weather today. I'll redeem it on my way back.'

The Captain accepted the umbrella, Goodyear went to the pawnshop and handed the ticket money to the Captain on his return journey. 'Here's your umbrella, and good luck to you —it looks as though you'll need it,' smiled the Captain.

His name was Cornelius Vanderbilt, the future millionaire industrialist.

THE 'MIRAGE'

As suddenly as his luck had left Goodyear it returned again. New York was no good to him, so he tried Boston. He paid a visit to Mr Chaffee, whose Roxbury Company had failed and whose factory was idle. Goodyear persuaded him to let him use some of the machines to produce rubber goods with the help of his new nitric acid process. Within a few months money started to flow into his pockets again, and he moved his family—who were by now quite used to these ups and downs and changes of place—to Massachusetts, near the Roxbury factory. By the end of the crisis year, 1837, he had five thousand dollars in the bank.

At nearby Woburn, he met a Mr Hayward, who had been foreman with another rubber company, which had also become bankrupt. Hayward was carrying out experiments on his own in the abandoned factory. He had tried to sprinkle sulphur over rubber sheeting, and dry it in the sun—with results very much like those achieved with Goodyear's nitric acid process. Goodyear bought Hayward's idea, which he regarded as better than his own, and patented it. With his own money, he hired the factory and Hayward with it. He was now controlling the only two process which seemed to have any future in the development of rubber. Yet he was still on the wrong road. Another chance accident was necessary to open his eyes.

He started production of life-jackets for steamship companies, and of rubber mailbags for the federal govenment. The first big orders were nearly carried out when he made a business trip to New York to secure more. He returned in the middle of a heat wave a few days later, expecting to find everything ready for shipment.

An ominous odour met him when he walked up to the factory gate. He threw open the warehouse door. A vile-smelling mass was the first thing he saw on the floor. He could still distinguish the distorted outlines of the life-jackets and the mailbags. He looked up to the pegs where the completed mailbags had hung.

Only the handles were there. The rest had melted in the heat wave: sulphur-sprinkling and aqua-fortis had not produced sufficient heat-resistance.

Again, Charles Goodyear was beaten—the secret of rubber was still unsolved.

It is a strange fact that inventors, as a rule, rarely grasp the dramatic power of the scene and setting of their discovery; and when they write about it they usually tell their own thrilling story in a few dry lines. Goodyear, for instance, recalled his great achievement in these words:

'While on a visit to Woburn, I was surprised to find that a specimen, being carelessly brought into contact with a hot stove, charred like leather. I directly inferred that if the charring process could be stopped at the right point, it might divest the compound of its stickiness.'

The real story behind these lines was that one day in February, 1839, Goodyear's wife, Clarissa, had a long and serious talk with him. His savings had gone again. The furniture was sold under the auctioneer's hammer. Clarissa was heartsick over the endless sacrifice for an idea that might never become reality, heartsick to see her children in shabby clothes, to hear them asking for food when there was so often none in the house.

'Give this thing up, Charles,' she begged. 'It's like a mirage; the closer you approach, the more it recedes. I don't think you'll ever get there.'

'But, my dear, I know I'm close to the solution of the problem. Any day might bring it,' he replied.

'All right, go on with it if you must. But do it in your spare time, as a sideline. Take up some work that keeps us from starving. Promise, Charles, please—for the sake of our children!'

'All right, Clarissa. I promise.'

But his mind could not dismiss the rubber problem so easily. A few days later, while Clarissa was at the market, he was again mixing some rubber and sulphur in the kitchen when he suddenly heard her returning. Afraid that she might make another scene, he threw the whole mass into the kitchen stove. Clarissa noticed a curious smell but she said nothing. As soon as she left the kitchen again, Charles Goodyear opened the stove and looked for his rubber. He found himself at the end of his journey—there it was, the 'mirage' become real!

It was a remarkable accident, for heat was the very last thing Goodyear, or for that matter anyone else who knew the properties of rubber, would have thought of applying; it was common knowledge that it would soften at 100 degrees, and dissolve at 200. Who would have guessed that the right way to make rubber a practical and usable material was exactly what Goodyear had done by chance—mix it with sulphur and subject it to great heat?

FOUR YEARS AND A FORTNIGHT

No fanfares greeted Godyear's great discovery. There was nothing to show but a charred piece of rubber. He realized that he must find out the exact degrees of heat and lengths of time necessary to 'cure' the rubber for the manufacture of a wide range of articles, and get a smooth surface. He made up batch after batch of the sulphur-rubber compound, and put it into the oven for one, two, three, or six hours. He tried open fires and steam heat, hung it in the tea kettle from the handle, boiled it in saucepans, roasted it in ashes and in hot sand, used a slow fire and a quick fire. He asked workshop owners if he could use their ovens after working hours. Everybody regarded him as a harmless lunatic.

He got no further financial backing. The very word 'rubber' made people turn their backs to him. He had succeeded, at last, in convincing his doubting family that he had found what he wanted; but no one else seemed interested. He did not patent his process for four years.

The winter of 1839-40 was very cold and bitter. The family was living on their neighbours' charity. Goodyear's health suffered terribly; he feared he might die before he had a chance to convince the world of his discovery, and that no one else would bother to carry on his work. He had to sell his library, even the children's school books for food. They dug half-grown potatoes from the fields, and went into the woods for fuel. Yet he would not give up. 'I'd rather beg for bread,' he declared.

Then there was an incident which shows the kind of man he was. A letter with a fair-sized cheque arrived from France: a company there wanted to buy the French rights of his nitric acid process, of which they had heard. He returned the cheque. 'I have since found a better process,' he told the French company. 'I will write you as soon as my tests on the new process are completed.' That night there was not a stick of wood or a bite of food in the house, and Goodyear, rather than take money for an obsolete process, went to a man he had only seen in the street a few times, and asked him for a loan. The man lent him enough to feed his family for a few months, and to continue his experiments.

He went to Boston to raise some money for a pilot plant using his new process. He failed and was unable to pay his hotel bill of five dollars. He was thrown into jail again. 'It's as good a resting place as any this side of the grave,' he said to his jailers. On his release, he walked fifteen miles to his home—to find his youngest son dying. He forgot his pride and wrote begging letters. Some friends sent him a few dollars, another a barrel of flour; but all of them advised him to get out of the rubber business.

He would not listen. He felt that his health was fading, and that this was a race against time. Eventually, his wealthy brother-in-law put a considerable sum of money at the disposal of Charles Goodyear and his brothers—that was the condition—to produce goods that would sell. Charles left the running of the business to his brothers and set up his own little production of rubber goods: sails for ships, walking sticks, pocket combs, cutlery with rubber handles, watch cases, and book covers; also rubber floor tiling, 'agreeable as carpet, durable as oak'. This was the happiest time of his life; he had enough to live on and continue his experiments. But the death of his father, Amasa Goodyear, and of his younger brother, cast the dark shadow of tragedy on the family; for the two died of yellow fever in Florida where they had gone to plant and market oranges—the first plantation of its kind in the United States.

Still Charles Goodyear had not patented his process of treating rubber with sulphur and heat. He wanted to file his applications simultaneously in the United States, England, and France, and this involved a great deal of formality and red tape. His American patent was at last granted; but at the same time he learned that the British Government had granted a patent to one Thomas Hancock for an identical process—which Hancock called 'vulcanization'—only a fortnight earlier! From that day, the rest of Goodyear's none-too-long life was spent in passionate and often furious controversies and legal dog-fights about the priority of the vulcanization process. Only much later, Hancock admitted that the first vulcanized rubber he had seen was a sample which Goodyear had sent to England, in order to sell the manufacturing rights.

A WORLD OF RUBBER

For eight years Charles Goodyear battled against another claimant, an American manufacturer; but in the end a Federal Court decided that Charles Goodyear was the rightful owner of a patent which was already growing to be one of the most valuable of all time. The ruling of the court sounded almost like an epitaph to Goodyear the inventor: 'When genius and patient perseverance succeed,' it said, 'in spite of sneers and scoffs, in perfecting a valuable invention, how seldom is it followed by reward? Envy robs him of the honour while speculators, swindlers, and pirates rob him of the profits.'

In 1851, Goodyear sailed for England with a number of exhibits for the first World Fair at the Crystal Palace, and with the hope of getting a reversal of the patent awarded to Hancock. Britain, however, though paying tribute to the rubber goods which Goodyear exhibited, left the patent with Hancock.

Another great exhibition beckoned Goodyear and Clarissa, who had come with him across the ocean, to Paris. He sank no fewer than $50,000 in an impressive rubber exhibit, hoping that contracts with French manufacturers would bring in millions. But the makers of the exhibition stand clamoured for their money. He asked them to wait a few days longer. It was of no avail, and one night in December 1855 there was a thunderous knock at the door of his hotel room; 'Police!' And again Charles Goodyear went to jail, only this time in an unheated brick cell in the notorious Clichy prison, with a stone floor and a straw shake-down for a bed. Clarissa begged the magistrate to let her stay with her husband to nurse him, for he was in poor health.

'I'm sorry, madam,' said the magistrate, 'that would be against regulations.'

Goodyear spent sixteen terrible days and nights in prison. In the meantime, friends tried to get him out; they even appealed to the Emperor Napoleon III, who at last ordered his release. The poor man had at least one consolation—the Cross of the Legion of Honour, one of the highest French decorations, was sent to him while he was in that icy cell!

For some technical reason the French patent was refused, and he left that country without regrets, to recuperate his health and spirits in England. He spent two years at Bath, living on the money that was at last forthcoming from his American ventures.

Had Charles Goodyear not been harassed, in his last years, by impatient creditors, money-lenders trying to extort enormous interest charges, patent-pirates attacking him with lawsuits, and by the unreliability of friends and business associates he had trusted —had he been spared all that he would surely have lived to see his invention triumphant, and to reap the reward he deserved. As it was, these struggles and disappointments cut his life short. In June 1860, he received an urgent call at Washington to come to New Haven where his daughter was dangerously ill. When he arrived in New York it was thought that he should go by boat as his own health could not stand a train journey. But the sea was rough, and he was taken off the ship and moved to a hotel. There he received a message that his daughter had died.

That was fate's last stroke against the unhappy man. The next day—1 July 1860—he closed his eyes for ever. Yet even then his family's troubles were not over; for he left a debt of two hundred thousand dollars. No wonder that even his own children considered Goodyear's life a failure, and that none of them touched the stuff that had brought so much misery upon them—rubber.

It took nearly forty years before Goodyear's name was vindicated and his great achievement acknowledged by a new and more grateful generation. A firm bearing the name of Goodyear, in recognition of his pioneer work, was established in 1898; it is now the largest rubber company in the world—a world that revolves on vulcanized rubber. When Goodyear discovered his process in 1839, only a few railway trains were jolting across the country, using inefficient hand-brakes; greater speed was only achieved after the introduction of the air-brake, which would have been impossible without rubber. The steam-boat also needed vulcanized rubber in a number of appliances. The motor-car and the bicycle could not have come into use so quickly and so widely, nor would the millions of miles of hard-surfaced roads have come into existence without the invention of the rubber tyre. The electric industry needs rubber for insulation, the aeroplane could not exist without it, there would be no modern electrical industry, no blood transfusion, no high-speed printing, no Wellingtons and raincoats—to mention only a few articles—without rubber made indifferent to temperature changes by vulcanization. It has increased the wealth, health, and comfort of the world enormously. For that, we have to thank a man who endured endless years of poverty, derision, sickness, and imprisonment to lead an unwilling mankind to a world full of rubber, which he was not destined to see with his own eyes.

5. *'A GIRL'S BEST FRIEND'*

ELIAS HOWE AND THE SEWING-MACHINE

'A bas les machines!'

The crowd surged forward through the narrow suburban street. There was a clatter of shutters being closed hastily by trembling hands—the citizens of Paris knew that once the fury of the people was excited there was no telling what they might do. They converged on an old house which had a workshop on the ground floor. A head popped out of the door to see what it was all about.

'C'est lui! C'est Thimonier!' yelled the crowd. The sound of smashed glass mingled with their angry cries. Those in front were pushed into the workshop by those behind. 'Get him! Get Thimonier! Hang him! Smash his devilish machines!'

They found the workshop without its owner. M. Thimonier had escaped by the back door. Now the fury of the demonstrators turned against the machines that were standing in the shop, ready to be delivered to buyers. They were systematically broken up and destroyed—dozens of them. Only when the last wheel and spindle had been trampled underfoot did the infuriated crowd recover their senses.

'That's the end of M'sieur Thimonier and his sewing-machines,' they said to each other, and went home satisfied. Perhaps they would now find work; for they were all unemployed tailors and seamstresses who believed that their livelihood was threatened by that new invention.

Barthélemy Thimonier was a tailor himself. Born in St Etienne, he moved to Paris as a young man, and took out a patent for a sewing-machine in 1830. It was a bulky, pedal operated affair with a crocheted needle that could make a chain-stitch, and government contractors who had received large orders for uniforms asked him to build eighty machines. The first batch of them was just completed when the unemployed tailors heard of the invention which, to their mind, would have meant semi-starvation for most of them.

Thimonier took the incident which nearly cost him his life as a warning, and never touched the sewing-machine again. He was neither the first nor the last sewing-machine inventor; it was such an obvious idea to attempt the mechanization of a repetitive, time-wasting, boring type of work. Spinning and weaving had been mechanized; why not sewing as well?

Thomas Saint, an English cabinet-maker, took out a patent in 1790; his machine was designed mainly for leatherwork, and had a piercer as well as a needle. But it did not prove to be very efficient. Then there was an Austrian tailor from Kufstein, Josef Madersperger, who improved the Englishman's design about twenty-five years later, by fitting it with two needles instead of one. However, Madersperger's colleagues, like Thimonier's in the 'thirties, feared that the machine would deprive them of their work, and the inventor did not get farther than the Vienna almshouse, where he died penniless.

In 1834, Walter Hunt in New York built a machine with a curved needle with the eye in its point and an oscillating shuttle beneath. It made a lock-stitch not unlike a modern sewing-machine. But as Walter Hunt was infinitely more successful with another invention of his, the safety-pin, he did not bother to look for backers for the machine—as though he had foreseen the struggle and frustration which was to be the lot of the man who eventually succeeded in ushering the sewing-machine into a world that was not quite sure whether it wanted that invention at all.

A CLUE OVERHEARD

'And what do you want, my boy?'

'Work, Mr Davis.'

The lad who had entered the workshop of the best-known mechanic of Boston, Mass., did not create the impression of being strong and healthy. He was pale and thin, and as he followed Mr Davis to his office he limped a little. The old mechanic made him tell his story.

'My home is at Spencer, in Massachusetts, Mr Davis. My father is a farmer. But we never were really well off. I had to start working when I was six.'

'What about school?'

The lad did not seem very happy about this question. 'Well, Mr Davis,' he replied after a moment, 'I went to school only for a few years, and only in summer—there wasn't any in the winter months. And when I was eleven my father sent me to another farmer in the neighbourhood to earn some money. But the work was too heavy, I couldn't stand it. I returned home and worked in my father's mill. We could never make ends meet.'

'I'll be hanged if I understand this,' murmured Mr Davis, more to himself than to the boy. 'Why should good, hard-working, God-fearing people starve in this land of ours? Go on, son,' he said with a touch of pity in his voice.

'I thought if there were one mouth less to feed my people wouldn't be quite so hard up. That's why I went away, looking for work. I have learnt a great deal working in factories, and for a time I've been a weaver. Here are my testimonials, Mr Davis.'

'And why have you come to me?'

'I wanted to ask you for a job for some time. They're talking about you everywhere, and about the various machines you've built.'

'Are they?' Mr Davis smiled. 'All right, son, you can start right away. What's your name?' he asked without even looking at the testimonials.

'Elias Howe.'

Davis was not disappointed in the lad. He did his job well and became an efficient mechanic. Within a few months he was the old man's chief assistant. But his ambition reached higher than that. He wanted to get on in the world. He wanted to invent something, build some new machine to relieve other workers from manual labour. He kept his eyes peeled and his ears pricked for some clue.

Chance intervened. One day in 1841, when Howe was 22, two inventors saw Mr Davis and asked him to build a machine they had designed. They showed him their blueprints in his office, and Howe was just passing the open door when he heard his boss remark, 'Why do you tire yourselves out with this knitting-machine for fishing-nets? I'll tell you what you'd have to invent to make real money—a sewing-machine!'

That was all that Elias Howe heard. But the idea got hold of him. Invent a sewing-machine. . . Yes, that was what he would do! He was not sure whether this was a theft of someone else's idea; but he overcame his moral scruples. After all, it was not a ripe fruit which had fallen in his lap, but a seed that had to be carefully nursed by himself. He was prepared to risk everything for it—his career, his family's security: for he was married and had a child. As Davis's first assistant he had a well-paid job. Yet he gave it up, and began to build the model of a sewing-machine. He went to work methodically, studying previous attempts made by other inventors. And the more he concerned himself with the problem, the more he became convinced that such a machine would be a boon to mankind. The demand for clothes was rapidly increasing, the textile trade expanding. Industrial development was making enormous strides. He was sure that he would succeed where other inventors had failed.

SEAMSTRESSES VERSUS SEWING-MACHINE

He worked day and night to perfect his model. Not unlike Madersperger, the Austrian tailor-inventor, he started from the idea that the machine should emulate the movements of the human hand. But somehow it would not work out as he had expected. Months went by, and still he had not found the basic solution of his problem. Hard times came for him and his family. Soon there was no more bread in the house.

Chance, however, intervened again. He happened to pass a weaver's house in 1844. The man was sitting at his loom near the window. Deep in thought, Howe watched him working, and remembered the time, many years ago, when he himself had sat at the loom. He saw the shuttle glide to and fro . . . to and fro . . . forming a knot every time. All of a sudden an idea struck Howe. He gazed at the shuttle in fascination. 'That's it!' he cried so excitedly that the weaver thought a madman was staring at him, and shut the window in Howe's face.

The inventor ran home, and went to work. He tried to copy, on a smaller scale, what he had seen. Within a short time he built a model in wood, for he could not afford any metal. It had an oscillating shuttle, and the needle had an eye through its point. When it was nearly ready, Howe and his family were on the verge of starvation; he could not ask his father for help for there had been a fire on the farm, and things were worse than ever at Spencer.

At the eleventh hour, however, help came from unexpected quarters. George Fisher, an old schoolmate of Howe's who had made good as a coal and wood dealer in Boston, invited the inventor and his family to live with him, and lent him money to build a working model of metal. 'Don't worry about paying back,' said Fisher. 'One day your machine will be a great success, and then we can talk about refunding the money!' They were both sure that this was only a matter of a few months.

The new model was ready in April 1845. In order to prove its efficiency to Fisher and to show him his gratitude, Howe sewed him a suit on the machine, which could make three hundred stitches per minute. Fisher liked the suit very much, and was full of admiration for the machine. 'I believe your seams are even more durable than the suit itself,' he joked. 'Now let's show the machine to the world!'

But this was easier said than done. Howe went to Boston's best tailor, and asked him to try the invention. 'I'm afraid you are wasting your time,' the tailor interrupted him after the first few sentences. 'I can't be bothered with such bunkum.' Howe was dumbfounded. Despite the warning examples of his predecessors he had been convinced that humanity had been waiting for his invention. He saw another tailor, and a third one, with much the same result: sneers, rejection, and indignation instead of appreciation and gratitude. He reported to Fisher about his frustrating experiences.

'I refuse to be discouraged,' said Fisher. 'Stupid blockheads, that's what they are. But we'll show 'em! I've got an idea. You must boost your machine. We'll stage a bit of ballyhoo in true American style!'

'Sure, that would do the trick. But how?'

'We'll organize a sewing competition—seamstresses versus sewing-machine!'

Fisher's instinct was right. The event became a sensation, and everybody was talking about it. The five fastest seamstresses of Boston were tempted, by the prospect of winning prizes, to take part. Boston's clothing trade was fully represented in the hall which Fisher had rented for the purpose. An independent jury was elected; among them was a certain Mr Bliss, whom we shall meet again on a later occasion.

Six identical pieces of work were given to the girls and to Howe, who insisted on operating his machine himself. The competition, however, ended rather early when Elias Howe submitted his finished piece to the jury after seven minutes; the girls sewed with all their dexterity for thirty-five minutes! The jury examined the pieces most critically; but it could only come to the conclusion that the machine had done its work not only five times as fast, but more neatly than the human hands. Thus the first practical sewing-machine had come out top, and Elias Howe was in a triumphant mood. Surely his worries would be over at last!

Only now was he to experience the sad lot of an unlucky inventor.

SEWING-MACHINES WITHOUT HOWE

Contrary to Howe's and Fisher's expectations, the competition had no immediate results. The reason was that all those who inquired about the machine were put off by its high price; it cost Howe himself three hundred dollars to make. He took out a patent for his shuttle and lock-stitch system, and tried to sell manufacturing rights. No one wanted to buy them. Eventually, even Mr Fisher had reached the limits of his patience and magnanimity.

'Look here, Elias,' he said one day, 'I've spent five thousand dollars on you so far. I'm sorry, but I can't do more for you. I hope you'll understand.'

'I understand, George,' said Howe. 'We'll pack tomorrow.'

Elias Howe had left his father as a boy, without a cent in his pocket. Now he returned just as poor, but with a wife and child, and asked for help. The old farmer shrugged his shoulders. He would have liked to assist Elias, but things had not improved for him; all he could do was to feed him for a while with the little there was on the farm, and eventually Elias found a job as an engine-driver.

As they sat around the family table, Elias's younger brother, Amasa, who had been working as a salesman for a manufacturer, produced an idea which everybody thought splendid.

'Look here, Eli,' he said, 'there has been some talk about sending a fellow from our firm over to England to sell our goods. I'll get my boss to pick me for the job. Then I'll take along your model and the patent papers, and try to find a backer in the old country. How's that?'

Amasa sailed in October 1846. After a few weeks his first letter arrived—a cry for help! He had spent his firm's money and did not dare to ask for more as he had not been able to sell anything. And no one in England wanted to touch the sewing-machine. Amasa's last dollars were running out fast. He was in a tight spot.

But neither Elias nor their father was able to help him, and so Amasa had to get rid of the model and patent at any price. He came across a business man called William Thomas, who ran a factory for umbrellas, corsets, and footwear in Cheapside, London. Mr Thomas realized at once that Amasa would be ready to agree to any terms, and he did not hesitate to exploit this situation. He bought the model for the trifling sum of $250 —including the right not only to use the machine in his factory but also to have as many copies of it made as he liked!

The bitter pill was, however, sugared by Mr Thomas's promise to take out a patent for the invention in Britain at his own expense, and to make sure that Elias Howe would get £3 licence fees for every machine sold in the United Kingdom. But as soon as Amasa had returned to America, Mr Thomas took out a patent —under his own name!

A few weeks after Amasa had arrived back in Massachusetts there came a letter from Mr Thomas asking the inventor to come to London to improve his model on the spot as some faults had developed during its use in the factory. He was to get a fixed salary and expenses. Elias, overjoyed, packed his things, firmly convinced that his invention had already begun to conquer the world.

Yet in Cheapside he found a different Mr Thomas from the man who had written that friendly letter: a shrewd business man who knew only too well that he had the whip-hand of the down-and-out inventor. At a salary of £3 a week, Howe, who had brought his wife and child with him, had to adapt his machine for the sewing of corsets. In addition, Thomas treated him so badly that at last Howe's nerves gave way. He entered Mr Thomas's office.

'Say, Mr Thomas, this is really a bit too much,' and he held a piece of paper under the Englishman's nose. 'I found this on my machine this morning. *Will you stop talking to my workers during working-hours. You are stealing my time.* Signed, William Thomas.'

'Well, what's wrong with that, Mr Howe? Haven't you been stealing my time by chatting to them, telling them stories about America? I haven't engaged you as a story-teller.'

'Stealing your time—indeed! I wonder who's stealing what in this house. What about my English patent?'

'Well, what about it? Go on, sue me, you nincompoop.'

'You pirate! You—you slave-driver! I'd rather die in the gutter than stay with you a minute longer!'

And Elias Howe walked out, slamming the door behind him.

Penniless and without friends in a foreign country, his only possession was the American patent for the sewing-machine. He hawked it around every pawnbroker in London. Finally he succeeded in getting a small sum for the document, just enough to buy one and a half tickets to America—for his wife and child—on an emigrant ship. He himself worked his passage as a cook on the same boat.

Howe was hardly out of sight when Mr Thomas hastened to take up the production of sewing-machines to the inventor's improved design. The theft of the patent rights, it is sad to report, brought Mr Thomas a great fortune; for the machines became an unqualified success in England, and were introduced into numerous industries. Soon Mr Thomas was able to retire, and live in luxury on his licence fees, £2 per machine. . . . For a few years at least he forgot everything about the inventor he had cheated out of his rights.

The ship on which Howe and his family were returning went to New York, and when he had paid his wife's fare to Boston there were only sixty cents left, and he took a job in a machine shop to make a few dollars so that he could join his family again. Before he had reached that point, however, he learned that his wife was dying in Boston. He borrowed some money for the ticket, and arrived just before she passed away. Poor soul, she had never known anything but poverty and hunger, false hopes and humiliating charity at his side.

A few days later Elias Howe received a message to the effect that the ship which carried his few household possessions back from England had sunk in mid-ocean. He felt that there was nothing more that Fate could do to him; that this was the lowest possible point in his fortunes. But he was wrong.

One morning he opened the newspaper. A headline on the front page arrested his eye. It read:

SEWING-MACHINES—THE GREAT NEW INVENTION!

With his heart furiously palpitating, he skimmed over the article to find his own name. It was not mentioned. Some one else was credited with 'the great new invention'.

TRANSFORMATION SCENE

He had been cheated out of everything. He had lost whatever he had possessed. His family life was destroyed. Life was not worth living any more; for what hope was there for Elias Howe? It seems almost inconceivable that he did not give up the struggle there and then. But he was one of those people who never admit that they are beaten. He swore to take revenge. Within a few days he learned everything that had happened during his absence from the States.

A former leader of a troupe of strolling actors had somehow got hold of Howe's idea, teamed up with a Boston business man, and developed a practical single-thread chain-stitch machine.

When Howe saw it, he had to admit that it was an improvement on his own model, which was a lock-stitch machine. He paid a visit to the small factory which was turning out these machines; nobody knew him or recognized him. He asked for the boss, and was received by a sleek, polite man who introduced himself as Mr Clark. 'And what can I do for you, Mr—er——'

'Elias Howe. Does the name mean anything to you?'

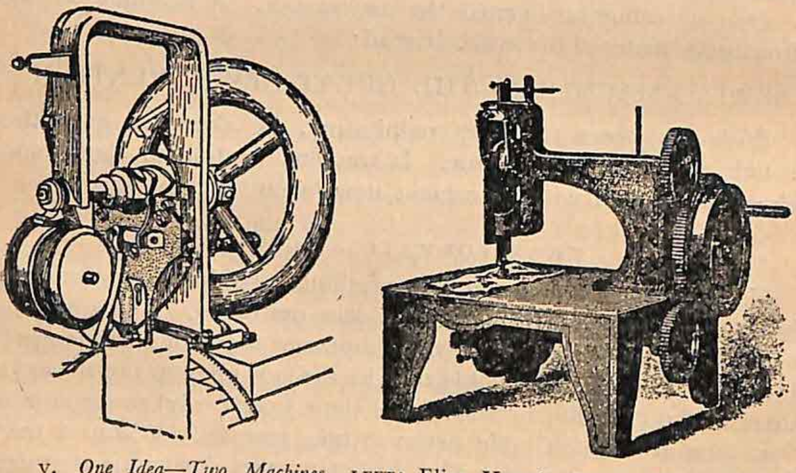
'Howe? No, I don't think that I ever had the pleasure.'

'Have you ever heard of my name in connexion with sewing-machines, Mr Clark?'

'Never—if my memory serves me right, Mr Howe.'

'Then let me refresh your memory—and that of your partner. I am the inventor of the machine you are producing in your factory.'

Mr Clark did not turn a hair. 'Oh, is that so? Well, surely you have documents to substantiate your claim! Where is your patent?'



v. *One Idea—Two Machines.* LEFT: Elias Howe's first model of his sewing-machine (1845); RIGHT: machine marketed by his rival in 1851.

In a London pawnshop, he might have replied. But of course he did not. He turned on his heel without answering. 'I'll sue them'—that was the only thought he had in his mind after that visit. But one cannot start a lawsuit without money.

As more than once in his life, he received help from an unexpected source. Mr Bliss, who had been a member of the jury at the sewing-competition, had been watching Howe's career from a distance. Now he appeared on the stage like the Fairy Queen in a pantomime to start the great Transformation Scene.

First of all he lent the inventor enough money to take the patent document out of pledge, and have it returned to America. Then he backed the big legal counter-offensive. Mr Clark and his partner were sued. Within a few months, quite a number of law courts were kept busy with the sewing-machine case. The defendants countered the attack cunningly, digging out old documents and patents to prove that Howe himself had stolen the idea. For some time, the scales of justice seemed to favour Howe, then again his opponents. Howe, with Mr Bliss's support, fought this war of nerves with untiring energy.

At last in 1854—seven years after Howe's return from England—the High Court pronounced its final verdict. It was more than a judgement, it was a tribute.

'The patent of the plaintiff Howe,' it said, 'is valid, the machines made by the defendants are an infringement of his patent rights. There is no doubt whatsoever that the blessing which the introduction of the sewing-machine has brought to all is due to the work of Elias Howe.'

Fate did not make a fool of Howe any longer. It began to heap on him the fruits of victory. He had been vindicated also from the moral point of view; the Court had called him a benefactor of mankind. Howe, the failure and pauper, became Howe the millionaire. Everyone making a sewing-machine had to pay him a licence fee.

The tremendous value of his invention became at last evident. After a few years he received no less than four thousand dollars a day in licence fees; in 1863 alone, two million dollars flowed into his pockets, and he did not have to lift a finger for the money. How had it been possible for the clothing factories, the tailors, the shoemakers, the housewives to manage without that machine for so long? The world had really been waiting for it. Far from creating unemployment, it opened the door to hundreds of thousands of women seeking work. The sewing-machine began to be called 'the girl's best friend'.

Howe built his own factory in Bridgeport, Connecticut; it survived him for more than sixty years, and produced a million machines.

At last he succeeded in taking vengeance on Thomas the Pirate. He secured for himself the right of demanding a licence fee for every sewing-machine imported into the United States: thus Mr Thomas, who had built up a lucrative export business with Howe's machines, was compelled to pay five dollars for every machine he sold across the Atlantic, to the man whom he had once blackmailed and exploited.

TEN HAPPY YEARS

Thus Howe settled his account with a world that had used him ill. But the richer he became the less he employed his power for selfish ends; for he knew better than most men how heavily poverty and distress weigh upon the underdog. When the American Civil War began he volunteered for the Northern Army as a private, eager to fight against the slave-drivers. He endured patiently all the hardships of the campaign and once, when the pay for his brigade failed to come up in time, he contributed thirty thousand dollars out of his own pocket. His noblest gesture, however, was his refusal to apply for a renewal of his patent rights when they expired in 1867, which meant a refusal of several million dollars' profit out of other people's labour. 'I don't want to make more money,' he said. 'I've made enough already with my invention.'

He appeared at the World Exhibition in Paris in the same year, a prominent figure with his impressive head, his thick beard rounding his chin, and his long hair. At Paris, he received one of the highest distinctions which the old world can bestow on an inventor, the Grand Cross of the Legion of Honour.

A few weeks later he died at the early age of 48 years—only the last ten of which had been happy.

6. *A BRIDGE UNDER THE OCEAN*

LORD KELVIN AND THE ATLANTIC CABLE

THE Commander and the First Officer of the British battleship *Agamemnon* were pacing the deck with nervous impatience. Sailors are superstitious. They never talked about it, yet each of them—and probably many of the crew—were convinced that an unlucky star was shining over the expedition about to start on 29 May 1858, from Valentia Harbour in south-western Ireland.

It was the second of its kind, the first having failed dismally. The whole idea was fantastic: that of laying a telegraphic cable from Europe to America—a kind of bridge under the ocean. Everybody on both sides of the Atlantic agreed that it would be a wonderful thing to have such a bridge, and to exchange news and messages between, say, London and New York in a flash by means of the new electric telegraph. But did the people who had thought this out behind their lecture pulpits and their account-books—did these people know what the Atlantic Ocean was like, that terrible, deceptive, unpredictable foe? Even the most powerful steamships of the day had to struggle hard against the forces of wind and waves to get their passengers and cargoes safely across; how much more difficult and dangerous was the attempt at laying thousands of miles of submarine cable across the peaks and valleys, the pinnacles and the unfathomable depths of the ocean bed!

Sailors and naval officers obey the commands of their superiors. Yet there was many a subdued grumble about the Admiralty's folly to lend the *Agamemnon* for this, obviously hopeless, task when the first attempt was made a year earlier. The *Agamemnon* had been teamed up with an American frigate, the *Niagara*, the plan being that both should sail from Devonport, each with half the length of the Atlantic cable on board; that the *Niagara* should 'pay out' her part of it first, and that the *Agamemnon* should sail on to America after the splicing of the two cable ends somewhere in mid-Atlantic.

But the plan did not work. The enormous cable mass—containing over 340,000 miles of fine wire (enough to go thirteen times around the World) insulated with gutta-percha, and weighing eighteen hundredweight per cable mile—made the ships very difficult to manœuvre, especially as the paying-out gear was rather crude. The brake mechanism which should have regulated the tension of the paid-out cable broke down, and after laying only three hundred miles of cable the dreaded accident happened: the cable broke at a depth of twelve thousand feet. The two ships returned to Devonport, their mission unaccomplished.

As was to be expected, blame for the failure was cast upon 'the professor', the only person among the planners of the undertaking who had taken part in the expedition. He took it bravely and carefully. To him, it was obviously just another experiment that hadn't come off. It was most infuriating for everybody on board to hear him say how much he had profited from the unsuccessful attempt, how much he had learnt about the electrical and mechanical side of the venture, and how he was looking forward to a second attempt. . . .

CHEERS FOR A SPOT OF LIGHT

And now it was 'the professor' again who was the cause of all the nervousness and impatience on board the *Agamemnon*. He had managed to get the same ship for his second attempt at laying the Atlantic cable. With his help, new machinery had been built and set up on board, seven hundred miles of fresh cable had been manufactured, and he had hinted that he had now designed a new instrument which would make trans-Atlantic telegraphy possible across 2,500 miles of water.

But where was he?

Time was getting short. The new attempt was to be made in a different way so that the splicing could be carried out before any cable had been laid, because it was felt that the ships would be more manœuvrable if not tied to the cable. Instead of setting out together the two cable ships, the *Agamemnon* and the *Niagara*, with their full cable loads still in their holds, were to meet at a certain point in mid-ocean, one coming from Ireland, and the other from Newfoundland, then they were to splice the cable, and sail home while paying it out. It was, therefore, essential that the *Agamemnon* should sail on time to keep her appointment.

Yet 'the professor' had not shown up. Perhaps he was suffering from a spell of absent-mindedness, as professors are liable to do, and had gone off to India or the North Pole instead of Valentia Harbour?

A small figure appeared at the far end of the quay. The First Officer looked through his telescope. 'There he is—at last,' he told the Commander, who heaved a sigh of relief, and gave instructions to sail as soon as 'the professor' arrived on board.

'We can't sail!' was the first thing he told the Commander. 'The instrument hasn't arrived yet—or has it?'

'I don't know what you are talking about, Professor. No instrument has arrived, but we've got to sail *now*, and hang all instruments!'

'Impossible. As the scientific leader of this expedition I must ask you not to sail until——'

'All right, all right, Professor. If you shoulder the responsibility for the whole darned expedition, you can just as well do without me.' And off went the Commander to his cabin.

Now it was 'the professor' who began to pace the deck. Would the instrument come at all? He had ordered its construction only two weeks ago in London, and sent MacFarlane, his assistant, to collect it while he himself had set out for Ireland from his home in Glasgow. He looked at his watch. The Commander was right, of course, and the *Niagara* must not be kept waiting; cable-laying was too precarious a job for that. His thoughts wandered off, to his calculations and formulae. He took his little green notebook out, and began to check his figures. . . .

'Hullo, Professor,' a voice said suddenly. 'I hope I haven't kept you waiting?'

There was MacFarlane, still out of breath from running, holding a small object wrapped in brown paper, with four legs sticking out.

'It's arrived! We can sail!' The professor took the object and patted it as though it were a baby while shouting to the First Officer. A deafening hoot from the ship's siren was the reply.

The *Agamemnon* put to sea. The 1,250 miles of cable had been safely secured in the form of an enormous coil in the hold of the ship. As soon as the ship was on her way, the professor set up his precious instrument in a special room aft. The Commander came in.

'Sorry, Professor. I was a bit uncivil, I suppose. Everybody is a little nervous. Well, and what is this thing here?'

'A mirror-galvanometer.'

'Oh, I see,' said the Commander. 'A mirror—what did you say?'

'To put it in one sentence,' said the professor, 'this is the only instrument sensitive enough to pick up the very weak electric impulses which will arrive from the telegraphic transmitters at the ends of our cable, when it is laid between the Old and the New World, and to show us at any point of the laying process if the cable is still in order and the current can get through. And when I say "show" I mean it. For you can *see* the current!'

'See it? Where?'

'Right here, on this scale—that little spot of light. It comes from this lamp here, reflected by the tiny mirror attached to the magnet. The weak electric impulse coming through the cable is sufficient to move the magnet, and the mirror reflects the light onto the scale so that we can see the impulse and measure its strength. The stronger the current the higher climbs the spot. Now watch this—I shall connect the galvanometer to the cable and send a current through it from this little battery.

Up went the spot.

'You see, the cable is still all right,' smiled the professor.

'I should hope so,' laughed the Commander. 'Well, this seems to be quite a valuable invention of yours, Professor. I think it was worth waiting for!'

In the middle of the night, MacFarlane woke up. The *Agamemnon* was tossing and rolling. He went up to the instrument room where the professor was keeping his watch. 'Let's go down,' said the professor. 'I'm very much worried about the cable.

There was every reason to be worried. The giant coil of cable was being tossed about in the hold like a piece of cheese. There was no telling what might happen before the storm was over.

Here and there, they could see abrasions of the gutta-percha insulation in the dim light of the oil lamps.

There was no question of going to sleep that night. The storm grew fiercer, and the anxiety on board mounted from hour to hour. If the cable was seriously damaged they would have to return and it was very doubtful if the Atlantic Telegraph Company could have afforded to try the seemingly impossible once more.

In the morning the storm subsided, and the professor decided to test the cable. The ship's officers filled the little instrument cabin. A witness has described the scene in these words: 'The professor, in a perfect fever of nervous excitement, shaking like an aspen leaf, yet in mind clear and collected, testing and waiting with a half-despairing look for the result. . . . Round the door crowded the sailors of the watch, peeping over each other's shoulders. . . . The eyes of all were directed to the instruments, watching for the slightest quiver indicative of life. Such a scene was never witnessed save at the bedside of the dying. . . .

'We looked at each other in silence. Suddenly one sang out, "Halloa! the spot has gone up to forty degrees! . . . The cable's all right!" Our joy was so deep and earnest it did not suffer us to speak for some seconds. . . .' Then, however, an ear-splitting cheer went up from everybody in the cabin and outside. The professor was so happy that he 'proceeded to congratulate those present on being connected with such an expedition'.

The joy and cheers, however, turned out to be premature. The trans-Atlantic cable had not been laid yet!

UNIVERSITY STUDENT AT 10

The professor's name was William Thomson. He was only 34, and hardly known in public; yet scientists all over the world were already familiar with his brilliant work. Many a physicist would have refused to put his ideas and inventions to the test by going on so hazardous an expedition as that of the *Agamemnon*. Thomson was a research worker who used his manual skill no less than his brains. He knew well that he owed his dexterity to his father, who had provided him and his brother James, two years his senior, with everything a couple of boys might wish for in the way of tools, space, and encouragement to make their own toys.

William Thomson was born in a Belfast suburb, in the comfortable house of a university professor. His mother died when he was quite young, and shortly afterwards the family moved to Glasgow. It was quite a big family—there were four sons and two daughters. Father kept strict discipline, but did everything to develop the natural talents which his children showed. He was also an excellent teacher, at the university as well as at home. 'All I learnt as a boy in English, geography, history, mathematics, and classics was taught me at home, along with my brothers and sisters, by our father,' William Thomson used to say later in life. How excellent a teacher his father must have been is shown by the fact that William matriculated at Glasgow University at the incredibly early age of ten years!

But he never regarded this achievement as anything out of the ordinary, and as an old man he said: 'A boy should have learned by the age of twelve to write his own language with accuracy and some elegance. He should have a reading knowledge of French, should be able to translate Latin and easy Greek authors, and should have some acquaintance with German: having thus learned the meaning of words the boy should study logic!'

Perhaps it is just as well that William Thomson's own exacting standards have never been accepted by the school authorities. The ten-year-old university student, however, was no prig. His laugh was so infectious that it sometimes got him into trouble. Once, at a religious service, he could not restrain himself, and the minister pointed at him angrily: 'Ye'll no laugh when ye're in hell!'

His scientific bent revealed itself very soon. For a year or so he spent a good deal of his time spinning humming-tops, rolling hoops, and flinging skipping-stones. But not for fun; he was interested in the problems involved in the action of these apparently simple toys. 'I have been investigating the theory of spinning tops and rolling hoops,' he wrote in a letter, 'which is very curious and difficult.' He pondered for no fewer than forty years over the problem why a spinning top would stand on its end!

He was a Cambridge student of only 22 when he was elected unanimously to the Chair of Natural Philosophy at Glasgow University. His youth had one great advantage: he knew exactly how his students' minds worked, and what he had to do to create the desired impression. Thus his methods of demonstrating his theories were a source of unfailing delight to his students. When he lectured on sound he brought a French horn along, which he had played when he was a member of the Cambridge Musical Society. The notes he produced in the lecture hall provoked cheers from the students, which he answered with a stern 'Silence!' Or he produced a rusty-looking rifle and fired shots with it when discussing the velocity of a bullet. This performance usually met with such applause and calls of 'Encore' that the professor, with a keen understanding of his students, obliged and repeated it.

Then again he told the story of how Columbus made an egg stand on end, but went one better than the discoverer of America—he made it stand on end *without* breaking it: by spinning it rapidly on a smooth surface so that it rose like a top. 'But it must be a boiled egg!' he told his students. Then he tried the same experiment with a raw egg; it remained in its horizontal position. Once the students tried to play a joke on him by substituting a boiled egg for the raw one before class. Professor Thomson spun them both, and remarked quietly: 'Both boiled, gentlemen!'

He married at the age of 28, but his wife—a very cultured, intelligent Scots girl—fell ill on their honeymoon and remained an invalid for the rest of her short life. William Thomson bestowed the greatest care upon her; he carried her upstairs and downstairs, kept her company, and did everything to keep her mind off her painful illness. He was heartbroken when she died.

He took up yachting to find a new interest in life, sailing along the Scottish coast during his summer holidays, and once he went as far as Madeira. There he was introduced to the principal family of Funchal, the Blandys. There were two girls who wanted to be taught the Morse Code by Professor Thomson. They all had a good time exchanging light signals in Morse between the house and the yacht and the story goes that this was the way in which the professor asked Fanny Blandy whether she would like to marry him. At any rate, when he returned to Falmouth from his excursion to Madeira he had his second wife with him. She brought happiness to him and to the family with her grace, her kindness, and her hospitality. She ran the scientist's house with scientific precision—unruffled even when the professor, as usual, came home much too late and everybody, sometimes including important guests, had to wait for dinner to be served. And unfailingly Dr Redtail, the parrot, croaked from his cage: 'Late again, old boy!' There was a suspicion that the butler, exasperated at these disruptions of the domestic programme by the professor's latecoming, had taught Dr Redtail these words. Cross-examined, however, the butler insisted that the parrot had learnt them all by himself.

HELD BY A DOG'S HAIR

At the age of 26 Professor Thomson had published a discovery which is still regarded as the earliest cornerstone of the whole edifice of wireless telegraphy and, eventually, broadcasting. Experimenting with the Leyden jar, then the only means of generating electricity, he came to the conclusion that induced electricity, although it may manifest itself in a sudden spark, moves in the form of oscillations; he tried to find the mathematical formula for that oscillatory motion.

More and more of Thomson's interest was drawn to electricity, especially to the telegraph. Submarine telegraphy had begun with the cross-Channel cable from Dover to Calais in 1851, and every daily paper had a news column headed 'By Electric Telegraph'. But the telegraphic connexion between Europe and America was still regarded as a dream of the future, comparable to our own speculations about a trip to Mars. Wire-drawing and insulating was a rather haphazard affair, for there were neither accurate instruments for measuring the electric capacity and resistance, nor machines for uniform production of the cable. Neither was there any experience of what dangers of the deep might be waiting for the submerged cable, and how to counteract them. When the Dover-Calais cable was laid people gathered on both sides of the Channel and voiced their criticism of that 'mad scheme'. Any sailor, they said, would confirm that it was impossible to pull a cable for twenty-five yards over such a rugged surface as the bottom of the sea—to say nothing of twenty-five knots!

The cable, however, was laid, but the telegraphic signals that came through were often chaotic and garbled. Professor Thomson was asked for his opinion, and found that electrostatic induction was the villain in the piece, retarding and messing up the signals. In a scientific paper submitted to the Royal Society he analysed the causes and suggested a complete solution to the problem of submarine telegraphy. When the Atlantic Telegraph Company was formed in 1856, under the energetic leadership of a New York businessman, Cyrus W. Field, he was appointed a director. 'If no accident happens,' he wrote to his German fellow-scientist, Helmholtz, 'electric messages will be passing between Ireland and Newfoundland before July 1857.' But accidents did happen. Thomson was on board the *Agamemnon* during that first attempt, when the cable began to run off the paying-out mechanism faster and faster over a depth of twelve thousand feet, and the brake was unable to stop it—until it had broken.

It was the mass of experience collected during that first cable-laying trip which prompted him to invent his mirror-galvanometer. He built the prototype himself—with a tiny magnet, able to respond to even the weakest current, made of a watch-spring and attached to the back of a minute convex mirror. The whole weighed only one and a half grains, and hung in the centre of a coil of very fine wire. Professor Thomson searched for some very thin and strong material to suspend the magnet and mirror in the coil. After trying out all kinds of fibres he called his little dog, Fairy, robbed her of a hair from her coat, and suspended his instrument from it. It was the perfect material.

WHALE BITES CABLE

The *Agamemnon* and the cable in her hold had got through the storm all right, and kept the appointment with the *Niagara* coming from Newfoundland. The cable ends were spliced in mid-ocean, the ships turned and began to steam back, paying out the cable. After the *Agamemnon* had paid out six miles of cable it broke. Again the ships met; a fresh splice was carried out. This time, a giant whale followed the *Niagara*—and bit the cable in two after eighty miles had run out. A third attempt was made. Again the cable broke, although the crew tried to mend a damaged part of the insulation while the cable was actually running off the mechanism!

Once more the ships met; and this time they got safely back to their respective ports. The trans-Atlantic cable had been laid. At the American end well-dressed ladies in white gloves helped to pull the cable ashore. The New World went crazy with excitement when, on 5 August 1858, Professor Thomson's message came through: 'Europe and America are united by telegraphic communication. . . . They are no longer separated by the Great Water. We have brought them together.' Queen Victoria and the American President, Buchanan, exchanged congratulations by cable.

But the joy was short-lived. The signals became weaker and weaker. One of the last messages to get through intelligibly was the cancellation of a British War Office order to British troops stationed in Canada; they had been told to embark for India to quell a rising of the Sepoys, but the rebellion subsided and the troops stationed in India were quite capable of handling the situation without reinforcements. It was estimated that the telegraphic counter-order, contained in no more than a dozen words, saved the Exchequer at least £50,000. The tremendous value of the cable could not have been demonstrated more clearly.

After 732 messages had been sent within three weeks, most of them by using Thomson's mirror-galvanometer, the cable ceased to 'speak.' It was a great disappointment, yet Thomson was not surprised. The cable was not made well enough, and it had been patched up too often. Perhaps another whale had got its teeth into it. . . .

For seven years, he took a vital and energetic part in preparing another attempt at bridging the Atlantic by cable. Standards for electrical measurements were designed, the paying-out machinery was prefected, and a new type of cable with much heavier armour, made to withstand the great stress of laying, was developed. To the critics who advised him to give up the whole idea as a bad job, he said, 'What has been done will be done again. The loss of a position gained is an event unknown in the history of man's struggle with inanimate nature!'

It was Thomson who persuaded his fellow-directors of the Atlantic Telegraph Company to try the new venture with the *Great Eastern.* She was the largest ship ever built—five times bigger than any other steamship in existence, with a displacement of more than 27,000 tons, and fitted with screw as well as paddle engines of altogether 5,300 h.p. In 1865, a new company was formed, The Telegraph Construction and Maintenance Co., mainly with the object of chartering the *Great Eastern* for the job. Professor Thomson superintended the manufacture of the new cable, hurrying from Glasgow to London and back nearly every week. When he was in Glasgow there was always a compartment reserved for him on the London Express, and more than once his secretary rushed into the station-master's office with the message: 'Professor Thomson asks you not to start the London Express on any account till he comes!' He was already such an important figure that the station-master complied with the request every time.

In London, he stayed with another branch of his family, who were used to his appearance at the oddest times. He had a latch-key, and his bed was always made for him. Once, in the middle of the night, his sister, the lady of the house, was awakened by someone trying to climb in through a window. She took a heavy walking-stick and was ready to hit the burglar over the head with it, when a well-known voice called out her name. 'I forgot the key,' and Professor Thomson apologetically, 'and I didn't want to wake you.'

He was, of course, on board the *Great Eastern* when the venture began, acting as the consulting expert. The first 1,200 miles were laid without a hitch. Then there was some trouble; the ship manœuvred to pick up the cable from the deep water—and it broke. The grappling-gear was brought out. Three times the cable was hooked and hauled up part of the way to the surface; but the shackles which were used to join the necessary lengths of grappling rope turned out to be too weak. Grappling gear and cable were lost, and the *Great Eastern* returned home.

It was decided to make a last attempt with the *Great Eastern* and an entirely new cable. A year was spent in manufacture and preparation, and in the summer of 1866 the new cable was laid at one go, without a single hitch. Thomson, who was again on board, suggested an attempt to recover the lost cable of the previous year. It was fished out from a depth of twelve thousand feet, joined to a connecting cable to America—and now there were two cables uniting the New World with the Old! Back in Valentia, Professor Thomson had the supreme satisfaction of seeing 'his' cable come to life in the mirror-galvanometer. The light spot flickered and moved, formed dots and dashes, letters, words, sentences, telegrams. . . .

Although he always claimed that his part in the laying of the Atlantic cable was not a leading one, all England thought differently. In November 1866, Queen Victoria bestowed upon him a knighthood 'in token of her appreciation of his services in connexion with the Atlantic telegraph.'

LORD CABLE

Seafaring men soon began to talk about Sir William Thomson with gratitude and respect, for he gave them a number of inventions which must have saved innumerable lives, ships, and cargoes. He loved the sea, and that was the reason why his mind kept grappling with nautical problems. 'I am a sailor at heart,' he would say.

It was in 1873 that he began to study the mariner's compass. It had good many faults; it was never steady when the ship was rolling, and it was subject to magnetic influences from the iron parts of the ship. Visitors to his yacht complained that they could not sit down in the cabin, which he had turned into his compass laboratory—there was castor oil, pasty paper, and whalebone everywhere. But he worked on that invention wherever he went, jotting down ideas in his famous little green notebook. Once, in a railway carriage, he looked up from his notebook and asked his wife absent-mindedly, 'Fanny, can you let me have a piece of whalebone from your corset?' For some reason, whalebone proved to be very useful in the construction of the first model of Thomson's compass.

After five years of work, the new compass was ready for a try-out.

This was done on a British warship, the *Thunderer*, going at full speed, circling, and firing her guns. The new instrument was on the bridge alongside the ship's own. The latter whirled round and round, failing completely; Thomson's compass worked with perfect precision! But it took another ten years for the Admiralty to decide to adopt it as the standard compass for the Navy. It has been the mariner's compass everywhere ever since. Its great advantages are extreme lightness of the 'card', reducing the friction at the bearing-point to a minimum. Instead of one heavy needle there are eight thin steel strips, fastened to the ring of the card with silk thread. The compass bowl is filled with castor oil to prevent rocking, and bars of permanently magnetized steel under the centre of the card correct the heeling error due to the ship's own vertical magnetism—to mention only the main characteristics of a wonderful instrument.

The reluctance on the part of the Admiralty to introduce the new compass was probably largely prejudice. So far, heavy and massive instruments had been used, supposed to be tough and hard-wearing. Sir William's compass was considered flimsy and fragile. Once, at a meeting of admirals and naval engineers, when the same criticism was made, Thomson picked up his instrument and threw it across the room! It took no harm. But when one of the engineers did the same thing to an Admiralty standard card it was damaged beyond repair.

Another important invention of Thomson's was his navigational sounding-machine. Cable-laying had made him wonder if the old-fashioned sounding system—with a rope and sinker—might not be modernized, especially as ships had to stop to take a sounding. His answer to the problem was single steel wire with a heavy sinker coupled to an automatic depth gauge, to be used while the ship was in motion. It also has become a standard navigational appliance, although modern ultrasonic and radar sounding have superseded it to some extent.

Perhaps the most wonderful instrument devised by this great brain is the Tide Predictor. It is an enormous cabinet not unlike a large switchboard, with knobs and wheels and handles, capable of analysing all the numerous and complicated constituents of the tides, carrying out the necessary computations, and predicting any given tide at any time and place in the world. The first of these instruments was made in a shop in Barnsbury Street, Islington—and so was the latest. It is one of the most complicated mechanical jobs, and there are very few Tide Predictors in existence; one is at the National Physical Laboratory in Teddington, another one in Liverpool (these two worked out the tides for D-Day in June 1944); most seafaring nations have one, and the first to be built after the second World War was sold to Russia for £5,000. It is still an indispensable helper in international navigation; for instance, the Teddington instrument calculates all the tides for the Indian ports months and years in advance. Although Sir William Thomson devised the Tide Predictor to work by mechanical means only, it may be justly called the forerunner of the 'electronic brains' of our time.

On New Year's Day 1892 Sir William received a peerage. It was typical of him that he was most embarrassed by everybody's congratulations. The honour took him completely by surprise—so much so that a family gathering had to be held to discuss his future name! All kinds of serious and not-so-serious suggestions were made: Lord Compass, Lord Cable. . . . Finally, his wife said, 'Why not Lord Kelvin?' The Kelvin is a beautiful little river flowing past Glasgow University, with lakes, swans, and ducks. So it was to be 'Lord Kelvin'.

He lived to a ripe old age, witnessing the start of a new century in which his beloved electricity was to develop beyond the most fantastic dreams. He could not, of course, foresee the innumerable applications of his many inventions in our time—for instance, the use of the resistance strain gauge in high-speed aircraft construction. Vibration and stress fatigue are two of the main barriers which limit the speed of aircraft. The resistance strain gauge is based on Lord Kelvin's discovery that the electric resistance of a wire when stretched varies in direct proportion to the charge of applied stress—a principle known for a hundred years. But only in our time has such a gadget been developed on a commercial scale: a fine wire of high electric resistivity wound on a thin insulating foil. The little instrument is firmly fixed to the structure to be tested, such as an aircraft body, and rapidly varying tensions are produced to test its behaviour under vibration and stress. The gauge measures accurately what otherwise could only be found out on the actual flight—when it may be too late.

Lord Kelvin was also at the cradle of wireless telegraphy. When Marconi set up the first permanent transmitter on the cliff above Alum Bay, on the Isle of Wight, Kelvin—then an old gentleman of 74—joined him in 1898 to take part in these experiments, which he recognized as immensely important. It was Kelvin who sent from this station the first paid wireless telegram. Today, there is a monument on the spot where the transmitter stood from 1897 to 1900.

Only a year before his death, in 1906, Kelvin said that he believed in electricity as the great peacemaker, which would bring 'universal alliance among the nations all over the world'. On the day before Christmas Eve 1907, he was laid to rest beside Sir Isaac Newton in Westminster Abbey.

Not very far from that venerable pile, on the opposite bank of the Thames, now stands one of Britain's most modern buildings, the Royal Festival Hall. Its comfortable warmth in winter is due to a magnificent technical achievement, the heat pump, which is a kind of refrigerator in reverse. Both the refrigerator and the heat pump owe their existence to Lord Kelvin and his heat-exchange principle, formulated over a century ago. Its first practical application, the refrigerator, has revolutionized the world's food trade and modernized our kitchens; its latest one, the heat pump, may well become the most economical way of heating our homes in the future.

7. *HOW NOT TO BECOME A MILLIONAIRE*

CHRISTOPHER LATHAM SHOLES AND THE TYPEWRITER

ONE midsummer day in 1867, a man without a hat and jacket walked into the machine-room of the Western Union Telegraph Company at Milwaukee, Wisconsin, grasped the telegraphist on duty by his arm, and told him categorically: 'Charlie, I've got to have a piece of carbon paper!'

Charles Weller, telegraphist and court stenographer, was accustomed to hear all sorts of crazy ideas and requests from his old friend Christopher Latham Sholes. 'If you want me to lend you ten bucks, Chris, you're welcome to them,' he replied. 'But carbon paper—impossible! You know I only get one sheet a day to copy my press reports. The stuff is too expensive. But you look terrible, d'you know? Pale, seedy, only half-dressed—you seem to forget that you are a senator, editor, and harbour controller!'

'Don't talk rubbish, Charlie, and give me the carbon paper. I didn't sleep a wink last night; I had such a dreadful cough.'

'What I'd like to know is how carbon paper can cure a cough. Is this another one of your hare-brained schemes?'

'Good heavens, Charlie, of course carbon paper can't cure a cough. I never said so, did I? What I meant was that last night, when my cold kept me awake, I got the idea what to do about that machine—you know, the one Mr Glidden was talking about. So come on and hand over.'

'I can only give you an old sheet, Chris, and there's hardly any black stuff left on it after yesterday's work,' Weller sighed, and fished a crumpled piece of carbon paper out of the waste-paper basket. 'Now leave me alone, I've got to finish transcribing this copy for the press.' And Weller got busy with his Morse telegram.

'I'm on my way, Charlie. Thanks for the carbon paper. And if you want to see something interesting, call at my office tomorrow afternoon. So long!'

'So long, and get yourself a bottle of cough syrup,' Weller called after his friend. What on earth was Chris up to with that carbon paper? Well, he would find out tomorrow.

Sholes raced through Main Street with his long strides, taking no notice of the passers-by, who stared after their well-known fellow-citizen in surprise. When he had reached his office in the Federal Building, he hung the notice 'Closed' on his door underneath the words, 'Harbour Duty Collector', locked it, and began to work on a pile of technical drawings.

THE LITERARY PIANO

Christopher Latham Sholes was, no doubt, the strangest man in all Milwaukee. He was 48 years old, and came from a family of fighters for the independence of the New England colonies. At 14, he began his career as an apprentice in a printing works in his home town, Mooresburg, Penn. He became an accomplished compositor and machine-minder, tried his hand at journalism, and took an increasing interest in public affairs. At 18, he was already an editor, and attracted much attention by his brilliant leading articles.

One day the printers of his newspaper went on strike. Sholes, holding a manuscript in his hand, looked at the idle printing-presses, and thought how much more dependable these machines were than the men who operated them; and how many more machines could be invented to supersede manual labour. A type-setting machine, for instance. . . .

At 25, he decided to start on a new career. He became a postmaster, and later took a job as a duty-collector. Then he was offered another job as an editor, this time on the influential *Daily Sentinel* in Milwaukee. Kenosha and Racine County elected him senator, and he contributed to the important legislative work of the period. When a big bribery scandal was discovered, Sholes turned out to be one of the few senators who had not taken a cent, while others had amassed fortunes by accepting money underhand.

He married and had several children. He took a growing interest in all innovations connected with printing. He had the idea of inventing a machine for numbering bank-notes, ledger pages, tickets, and so on. There was a workshop in Milwaukee, in the loft of an old store, where inventors and mechanics would meet and tinker to their heart’s desire. It was here that Sholes began to build a model of his numbering-machine, and that he made the acquaintance of another amateur inventor, Carlos Glidden, an attorney, fifteen years his junior.

Glidden, the son of an Ohio ironmonger, worked on an invention of his, a ‘spade-machine’ to relieve the gardener of the heaviest part of his job, the digging. Sholes and Glidden talked about this and that. One day, Glidden asked Sholes, ‘Why can’t you build a machine for printing the letters of the alphabet instead of these numbers?’

‘Funny you should mention that,’ said Sholes. ‘As a matter of fact, I’ve been thinking of it myself. Have you seen the latest issue of *The Scientific American*? Here, take a look at this.’

Sholes showed him an article on a machine recently invented in England by a certain John Pratt, the Pterotype or ‘literary piano’: an instrument for writing, or rather printing, letters without having to make a composition of types. The article prophesied that this machine would revolutionize every office.

‘I couldn’t say I agree with that forecast,’ said Sholes. ‘The thing looks rather clumsy and impractical to me. Still, the idea is sound.’

‘Sure. Why not go to work on it, Sholes? I wouldn’t mind investing some money in an invention like that.’

‘All right—let’s do it as partners!’

More than fifty inventors had tried to solve the problem of a writing-machine in various countries. Long before Mr Pratt’s Pterotype, English mechanics had built such instruments. The first known typewriter patent was granted by Queen Anne in 1714, but no description of the invention survived. The first American writing-machine was patented by William Austin Burt of Detroit in 1829; the only model was destroyed in the Washington Patent office fire of 1836, but the drawings published at the time showed that it looked roughly like a butcher’s meat block. In

1843, another American, Charles Thurber, tried to interest manufacturers in his invention, a writing machine in which the letters were arranged on a large, horizontal wheel; it was never manufactured, but there are still toy typewriters built on the same principle.

Sholes had to spend a good many sleepless nights, turning the problem of the writing-machine over and over in his mind, before he had an idea which he believed to be the solution. And that was what he needed Weller's precious carbon paper for.

THE MACHINE THAT WROTE 'WWWWW'

When Charles Weller came into Sholes's office the next day, he found his friend unshaved and paler than ever. All through the night he had been busy with his drawings and at the workshop; but now the strange machine he had seen in his mind's eye was created. Carlos Glidden, too, was in Sholes's office; he kept circling the table on which the machine stood, repeating: 'You've sure got something there, Sholes—I'm going to back you.'

Weller was now able to see for himself what his carbon paper had been wanted for so urgently. There was a Morse key standing on the table, with a lever fixed to it. The lever, which was swinging in a metal ring, had at its top a printer's type with the letter 'w'. When the key was pressed, the 'w' hit against a horizontal glass panel which formed the top of the gadget. When Sholes held the carbon paper and a piece of ordinary paper against the glass panel and then pressed the key, the letter 'w' would appear on the paper, printed by the type. Sholes moved the paper horizontally, pressing the key several times—and the gadget printed 'wwwww'.

'Not bad,' said Weller. 'But don't you think that an epistle consisting of only one letter is bound to be a bit monotonous?'

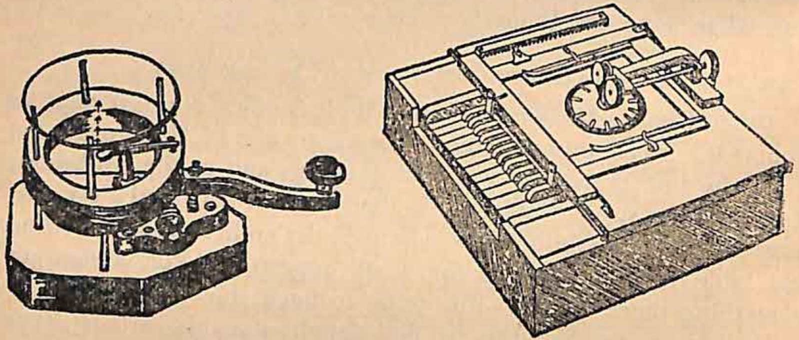
'Don't act the fool, Charlie! You only need to make such a key for every letter of the alphabet, and there's your writing-machine.'

'I'm afraid it won't be as easy as you imagine, Chris. But don't mind me. I'm a professional pessimist. Go on, build your machine, and I'll gladly admit that I've been wrong if it works.

More than that, I'll be the first to try it out. I'm going to start my new job as a court stenographer in St Louis next week; that would give me an opportunity of using the machine. By the way, what are you going to call it?'

'Writing-machine, of course,' said Glidden.

'No, that's not original enough,' protested Sholes. 'I think I'll call it "typewriter".'



VI. *Birth of the Typewriter.* LEFT: Sholes's experimental mechanism which could write only the letter W; RIGHT: his first typewriter model with a piano-keyboard.

In September 1867, the first working model of the new machine was ready for use—after eight weeks during which Sholes spent more time at night in the workshop than during the day in the Harbour Duty Collector's office. The model was an enormous box, not unlike a sewing-machine. Its upper part was mounted on a table, its core being a metal ring in which hung the type levers. The front part of the machine consisted of a sort of piano keyboard—Sholes got that idea from the 'literary piano' described in *The Scientific American*—with black keys; each of them was three inches long, and the letters of the alphabet were painted on them in white. In between the black keys, small white ones were arranged for the figures and signs.

The machine operated in a rather complicated way. Attached to the keys were wires which, through holes in the table, led down to a small tripod. Going up from the tripod, which rotated around a rod, was a second set of wires, corresponding to those leading down, and fixed to a set of type levers in the upper part of the machine. In this way, Sholes had attempted to solve the problem of the transmission of energy from the keys to the type levers: when a key was pressed the wire attached to it was pulled up, and the corresponding wire at the other side of the tripod pulled down, operating the type lever, which pressed a blackened ribbon (substitute for Weller's carbon paper) against a sheet of paper. Each time a key was pressed, the ribbon, running on two spools, moved on a little.

The paper, too, had to be moved on after each impression. It was, therefore, clamped to a metal frame which, like a wagon on cog-wheels, moved by a letter's breadth from right to left. As a motor for the paper-wagon movement, Sholes had built in a clockwork with weights, which had to be wound up from time to time. As soon as a full line had been typed, a small bell rang; then the operator of this machine had to step on a pedal that made the paper-wagon run back, and the paper moved up by a line.

The inauguration of this machine was quite an event. He asked all his friends to the workshop, including a newspaper reporter, and then sat down ceremoniously at his machine to type out the line:

'C. Latham Sholes, September 1867.'

For a few weeks he played with that model like a child with a new toy. Then he packed it in a large box, and sent it to his friend Weller in St Louis to be tried out in practice.

CONTRACT WITH AN ARMS FACTORY

Charles Weller, the world's first shorthand-typist, did his best to cope with the contraption. But he had to give in after a prolonged struggle with the shortcomings of the machine. The levers would get stuck, thus causing it to 'stammer'; the clockwork was unreliable because the leaden weights were too light. Weller weighted them with all the office utensils he could lay hands on, with the result that the wire broke and everything hanging from it fell on his pet corn. Soon the ribbon had to be renewed; Sholes made him a new one by buying a satin band at a haberdashery shop, pouring ink into a wash-basin, soaking the band in it, and stretching it between the chairs in his office overnight.

Sholes was by no means upset when Weller reported to him on his wrestling-matches with the obstinate typewriter. The inventor knew that he had to do much more work to perfect it; after all, a problem which had baffled inventors for over a century and a half could not be solved at the first attempt. So he made a new, improved model. But now he was running out of money, and Glidden was unable to invest more. Sholes, after turning his pockets inside out in the face of his wife's angry opposition, typed letters to all his acquaintances on the machine, asking them to invest money in his invention.

One of these type-written letters—the first to be produced in this way, and in themselves already an impressive advertisement for the machine—happened to be read by a Mr James Densmore, a well-to-do businessman and shareholder in an oil well, at Meadville, Pennsylvania. He offered to buy a quarter interest in the invention for six hundred dollars, without having even seen the machine. Sholes, in very urgent need of funds—Glidden had dropped out of the scheme completely—accepted, although he knew quite well that the typewriter must be worth either millions . . . or nothing.

Mr Densmore visited Milwaukee and Sholes in March 1868. He looked at the machine and shook his head. What he saw was the improved second model: a not-too-large box that could be put on any table. The type levers were fitted in steel bearings, and a foot treadle was used to operate the carriage return. And it was still a clumsy machine.

'I think it's good for nothing except to prove that your basic idea is sound,' said Mr Densmore to Sholes. 'You'll have to do much better than that if this machine is to revolutionize writing. You'll have to make at least a dozen more models until it's perfect.'

Sholes did not build a dozen models—but more than fifty! Each of them was better than the last, and never before had an invention been more carefully tested. Densmore shouldered the cost, which was around 250 dollars per model. The first one made under the new arrangement was sent to Mr James O. Clephane, a friend of Densmore's, the official stenographer to the Supreme Court at Columbia. 'Test it thoroughly,' he was told.

Clephane typed the machine to pieces and asked for a new, stronger one. He got it. He broke it to pieces. A third was sent to him, then a fourth and a fifth—with much the same result, until at last one of the models stood up to the strain. It looked very different from the early, primitive 'literary piano' model. The piano keys had now become round touch keys, arranged in four rows in such a way that the letters offered themselves in the most practical way to the fingers. The keys were directly connected with the type levers; the flat metal frame with its paper clips had been changed into an oblong carriage with a rubber cylinder for the writing-paper.

In 1871 Densmore decided to come out into the open with the machine, and exhibit it in New York. There it stood in a shop window for about a year. Some passers-by were nearly always to be found looking at it—but that was all. The business world took no interest yet in the typewriter. So Densmore decided to approach the Ilion Arms Manufactory, and wrote about the invention to the directors of the firm, Mr H. H. Benedict and Mr Philo Remington, in February 1873. He was invited to demonstrate it. Sholes, who hated everything connected with business, refused to go with Densmore; but the latter took a clever salesman with him, the fluent Mr George Washington Newton Yost, to do the talking.

Densmore and Yost showed the machine to Benedict and Remington in a small hotel room at Ilion, N.Y.

'Well, what's the verdict?' asked Densmore after Yost had explained everything.

'Very crude,' said Mr Benedict.

'But we'll make you an offer,' added Mr Remington.

On 1 March 1873, an agreement was signed between Densmore, Sholes, and the Ilion Arms Manufactory. It stipulated that the firm would build one thousand machines for a start, with an option on a world monopoly for the typewriter. The machine would be called Remington. Densmore accepted royalty payments on each typewriter sold. Sholes was to get an outright payment of twelve thousand dollars. Sholes knew very well what he was doing when he accepted, signing away all his rights for twelve thousand dollars. He had achieved his object: the world would have his typewriter. Densmore, too, knew what he was doing. The royalties he received during his lifetime amounted to one and a half million dollars.

'A MACHINE TO SUPERSEDE THE PEN'

As soon as the contract had been signed, the great factory brought its ample resources and the skill of its workmen into service to improve the machine still further. The Remington Model 1, ornamented in true Victorian style with flowery designs, was marketed in 1875. It was still fitted to a sewing-machine stand, with a treadle operating the carriage return, and cost 125 dollars. The first prospectus is worth quoting:

> THE TYPE-WRITER!
>
> A Machine to Supersede the Pen.
>
> Ministers, lawyers, authors, and all who desire to escape the drudgery of the pen, are cordially invited to call at our office, and learn to use the Type-Writer. Use of machines, paper and instructions, FREE!
>
> COPYING: A special department has been set apart for this purpose, and we are now prepared to do all kinds of copying, in the best manner, on the TYPE-WRITER.
>
> *The Work is Plain as the Plainest Print.*
>
> No pen-writing can compete with Type-Writing, either in
> SPEED, LEGIBILITY, OR PRICE.
>
> STENOGRAPHERS can come to our office and dictate to operators, *from their short-hand notes*, and thus save the labour of transcription. AUTHORS, who do not desire their manuscripts to go out of hand, can also dictate directly to operators; which saves the labour of revising and preparing a legible first copy for copyist, as such revision can be made when dictating to operator.
>
> DRAMATIC WRITERS will see the benefit of our *manifold copying*, in the fact that we can furnish *at the one writing* a COMPLETE CAST for every actor.

'Graceful and ornamental—a beautiful piece of furniture for any office, study or parlour,' the prospectus calls the machine. There were also a few testimonials from well-known people who had been asked to say what they thought about it. One came from a man who had the ear of all America: Mr Samuel L. Clemens, better known under his pen-name, Mark Twain. The Remington people knew that his words had to be taken with a grain of salt when they reprinted his letter in the prospectus of 1875:

Hartford, March 19, 1875

Gentlemen: Please do not use my name in any way. Please do not even divulge the fact that I own a machine. I have entirely stopped using the Type-Writer, for the reason that I never could write a letter with it to anybody without receiving a request by return mail that I would not only describe the machine, but state what progress I had made in the use of it, etc., etc. I don't like to write letters, and so I don't want people to know I own this curiosity-breeding little joker.

Yours truly,
SAML. L. CLEMENS.

What, in fact, had happened was this. The great humorist had bought a typewriter in Boston because he was enthusiastic about all new inventions. He took much trouble to learn how to work it, and after a few weeks' labour his publisher, Mr Bliss, received the first typescript ever produced by an author—an instalment of the immortal *Tom Sawyer*.

Mr Bliss was extremely pleased because, like that of most authors, Mark Twain's handwriting was illegible in the extreme. The publisher made Mark Twain promise to deliver only typewritten copy in future; but the promise was not kept for very long. The machine absorbed too much of Mark Twain's energy.

One day, he appeared at Mr Bliss's office, followed by a manservant stumbling under a heavy load—a box with the typewriter in it. 'My dear Bliss,' said Mark Twain, 'I herewith bestow upon you my typewriter. If I kept this monster in my room, I couldn't stand its reproachful look.'

The publisher did not know what to do with the gift. In the end he sent it back to Mark Twain. So the humorist had to look for another victim. Eventually he gave it to his secretary on the condition that he would not have to see it again; and that was that.

Slowly and hesitatingly, the typewriter gained the confidence of the public. When the first of these machines appeared in the shops nobody knew what to do with them, and in many offices the clerks began to campaign against the invention because they were afraid that they would have to learn to handle it or lose their jobs. Ink and pen manufacturers paid for newspaper articles denouncing it. Yet here and there, people began to use it—and to like it. The main difficulty encountered by the typewriter salesmen, headed by Densmore and Yost, was the high price of the machine. Why pay 125 dollars for a contraption to do the work of a pen which cost only a penny? That was the argument which kept a great many people from buying a typewriter.

The first popular success was achieved at the Centenary Exposition at Philadelphia in 1876, where visitors could have a short letter typed for 25 cents to send to their friends and relatives at home. Yet sales continued to remain disappointing for five or six years. The Model 2 of 1878 marked a step forward with its introduction of the 'key shift' for capital and small letters, or 'lower case' as the printers call them.

In Europe, the typewriter gained ground more quickly than in America. Remingtons entered the German market in 1883, and offices were opened in Paris in 1884 and in London in 1886. By 1890, the machine was already firmly established in England's business world.

In 1885, a special model was introduced in Russia with Russian characters. No other than Leo Tolstoy was the first European author to use the typewriter. He made his daughter practise on it, and began to dictate to her. She typed all his correspondence and many of his novels. She was Europe's first girl typist, the first of a vast army of women who found a new and congenial career at the keyboard of the typewriter. No other invention, with the exception of the sewing-machine, has helped so much towards the emancipation of women as that of mechanical writing. Around 1880, there was hardly a girl to be seen in the business quarters of the world's great cities; women did not even visit them. Today, they heavily outnumber the men among the daytime population of the commercial and administrative sections in every town; the typewriter has wrought this social change of fundamental importance. And the machines used by the girls of today have still the same keyboard, with only minor alterations, which Christopher Latham Sholes designed for his first commercial model of 1868.

He watched the progress of his invention without envy. When Sholes, then in his sixties, began to suffer from tuberculosis and had no money to go to a sanatorium for treatment, Densmore felt pangs of conscience and paid the inventor the cost of a few weeks' rest cure in Florida.

But it was too late for a complete recovery. In February 1890, Sholes died at the age of 70, leaving ten children. When Charles Weller saw him shortly before his death, he said to his old friend: 'You know, Charlie, all my life I've tried hard not to become a millionaire. I guess I've made a success of it.'

INSTITUTE OF EDUCATION FOR WOMEN
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8. *DYNAMITE FOR PEACE*

ALFRED NOBEL AND THE BARONESS

ONE afternoon in September 1864, a terrific explosion woke the citizens of Heleneborg, a suburb of Stockholm, from their after-dinner nap. A crowd gathered round the smouldering ruins that had been a house. A few police constables tried to keep a path free for the firemen and ambulance helpers.

'It's the Nobels,' said a neighbour. 'They must all be dead.'

'Yes, there can't be a living soul under that debris. There were four sons and the old man. As soon as I heard they were experimenting with a new kind of gunpowder I said——'

'Gunpowder? So that was it! I knew they had some kind of a laboratory. And there must have been some assistants in the house. I saw people going in only this morning. . . .'

The talk ceased suddenly. Hats were doffed. The stretcher-bearers emerged from the ruins, clambering over the rubble. Five times they went in and returned with shapeless bodies covered by blankets.

At the police station, a list was drawn up: the casualties. It was found that only one of the Nobels was among them—Emil, a 21-year-old student who had happened to visit the laboratory during his vacation from the University at Uppsala. The other four people killed in the accident were a mechanic, an errand boy, a maid, and a workman who had just called for some unknown reason. Immanuel Nobel, who had rented the house, had not been well that morning and stayed at home. Two of his sons were abroad, one in Russia and one in Finland. Only 31-year-old Alfred, who had actually run the laboratory, was a resident at Heleneborg. But he had not been in the accident either; he was attending a business conference in Stockholm about a new company for the manufacture of explosives, which he intended to form. For he had made an invention which, he believed, was of enormous importance.

But when he stood in front of his parents that evening to tell them of Emil's death, all hopes of developing his invention in Sweden seemed to have gone. The licence for making explosives would, of course, be withdrawn. The family would be on the rocks again—though not for the first time.

MERCHANTS OF DEATH

The man who was called Alfred Nobel—a name that was to become familiar to every schoolchild within a few years—was singularly inconspicuous, and no one passing him in the street would have given him another look. He was small, thin, with a pale complexion, and not at all good-looking: a colourless little fellow. Only his large, burning eyes and his high forehead might have hinted at an unusual personality. Those who knew him well were even more puzzled than those who did not; some even spoke of a 'split mind' in that frail and insignificant body; a man who was sensitive and callous at the same time, shy and outspoken, sociable and aloof, an idealist and a cynic. All these qualities showed themselves in turn during the dramatic career of Alfred Nobel.

Perhaps the answer is to be found in the national character of the people to which he belonged, the Swedes. Peace, prosperity, calmness, and diligence—we have come to associate these notions with Sweden, the largest and most important of the Scandinavian countries. Yet three centuries ago, the blood-curdling cry, 'The Swedes are here!' made the peasants of Europe take to the woods, the children and women sob and tremble with fear, and hardened soldiers' hearts beat faster. Destruction and plunder, arson and torture, cruelty and murder were then associated with the Swedish hordes that rampaged through Europe, spreading terror from the Alps to the Urals, serving their power-drunk kings and *condottieri*. Was there something of that long-forgotten side of the Swedish character left in the Nobels?

Immanuel Nobel's life was far from being peaceful. He was what has been called a 'merchant of death'—and without being ashamed of it. Having failed as an architect—he went bankrupt in 1833, the year of Alfred's birth—and as a rubber manufacturer, he tried his luck first alone in Finland and then in Russia; his wife and the children joined him in St Petersburg (now called Leningrad). Alfred was 9 years old, and moving from

Sweden to Russia meant that he left school for good at that early age. His mother tried to fill up the major gaps in his education.

Immanuel Nobel looked around to see what kind of business might have the best chances in Russia. The country, with its many sea coasts, always suspicious that other nations might harbour aggressive plans, was worried about its naval defences. Immanuel Nobel suggested a new type of mine, designed by himself. He managed to interest a Russian general in the idea; it was submitted to the Tsar, who liked it, and Immanuel Nobel began to make sea mines at much profit for himself.

Now the Nobel family was flourishing. They lived in a magnificent home, the boys were taught by first-rate tutors, and they moved in court circles. It was only Alfred's health that remained as a cause for much worry and anxiety. He had always been a sickly child. 'My cradle looked like a deathbed,' he once told a friend. His mother could not allow him to join in the rough-and-tumble games of his brothers and neighbours. His spine remained weak, and often he had to spend days lying on his back. Small wonder, then, that he tried to make up for his physical shortcomings by developing his mental powers. He read an incredible number of books on all kinds of subjects—from scientific works to Shelley's poetry. At the age of 15 or 16 he knew a great deal about history, literature, and philosophy; apart from his native Swedish he had acquainted himself with the Russian, English, and French languages.

It may have been this latter instance which prompted the 'merchant of death' to send Alfred out into the world with no other aim than to see things, meet people, and pick up useful connexions. Immanuel Nobel was proud of his sons; the two elder ones worked with him, one in the mine factory and the other in the office. Alfred, obviously the 'brain' of the family, was furnished with the necessary cash and went on a two-year tour of Europe and America.

His first stop was Hamburg; then he visited Copenhagen, Italy, Paris, London—while the Great Exhibition of 1851 was held at the Crystal Palace in Hyde Park—and New York. When he returned in July 1852, his help in Immanuel Nobel's firm was urgently needed. Tsar Nicholas's demands presented to the Turkish Sultan were arousing indignation in the Western capitals; the danger of war increased day by day. The Nobels were producing mines at top speed. So Alfred joined his father and brothers, thus becoming a 'merchant of death' himself.

THE DANGEROUS OIL

When the Crimean War broke out, the Nobels not only supplied all the mines for the Russian fleet but also some types of guns and other weapons. They even did the actual mine-laying in the Baltic. Nobel's mines were something like square boxes filled with gunpowder, with long iron poles stuck into the sides; when these were hit by a ship, the impact broke a glass tube which acted as a fuse in the mine, allowing sulphuric acid to pour onto a mixture of potassium chlorate, sugar, and sulphur. This produced a sharp flame, or minor explosion, which set off the gunpowder. The mines, however, did little damage to the British and French ships; they might have sunk some had the powder charge been two or three times bigger than the 8 lbs. which were used—or had there been a more powerful explosive. Alfred was well aware of these shortcomings, and for the first time the problem of an explosive mixture of higher power entered his mind.

When the war came to an end in 1856, the Nobels' business collapsed. Tsar Nicholas had died, and Alexander, his son, was an enlightened ruler who was at pains to get on better terms with the western world. Armaments were cut down to a minimum, and the contract with the Nobels expired. To make matters worse, a fire destroyed the works. Soon the creditors were clamouring for their money. Immanuel Nobel was again on the road to bankruptcy.

Alfred, the cosmopolitan of the family, was sent to the West in a last attempt at raising money. In London, no one saw any reason why he should invest money in a Russian armament firm which did not get enough orders to keep alive. But in Paris, Alfred succeeded in interesting one of the great bankers, and he returned triumphantly to St Petersburg with a substantial cheque.

The joy at Messrs Nobel & Sons, however, was of short duration; the firm was beyond saving, and a year later the creditors took over what was left.

Alfred, for whom the journey had been a great strain, was so disappointed that he fell ill and nearly died. When he was out of danger his father and mother returned to Sweden, taking with them their youngest son, Emil, and leaving Alfred in the care of his older brothers in St Petersburg. One of them married and moved to the bride's native town, Helsingfors (now Helsinki), the capital of Finland. Alfred, recuperating slowly, was trying to make up his mind what to do when a letter from his father set him off on research work in a certain direction. 'You remember the "explosive oil" we were once shown by Professor Sinin at the start of the Crimean War? He put a drop of it on an anvil, and hit it with a hammer, which made it explode. If we use that in our mines I think business would pick up again because it seems more powerful than gunpowder. It was a colourless, heavy liquid that looked just like salad oil. Professor Sinin called it "nirto-glycerine". Can you find out more about it, and how it can be made and used?'

Alfred went into the matter. There was indeed such a substance. An Italian professor by the name of Sobrero had discovered it in Turin in 1847; he dropped glycerine slowly on a mixture of sulphuric and nitric acid; when the emulsion was poured into water it sank to the bottom. Once he heated a drop of it in a glass tube, and the tube exploded with such force that the glass splinters cut his face and hands, and other people in the laboratory were also injured. Sobrero stopped experimenting with the explosive oil; it was too dangerous. A Dutch professor, who had taken up the Italian's investigations, lost his eyesight in a nitro-glycerine explosion.

Without losing any time in trying to analyse the chemical nature of the oil, Alfred began making small quantities, and exploding drops of it. The oil did everything that could be desired of a powerful explosive. But the difficulty was that a sure, simple way of exploding it was not yet known. Professor Sinin had used a hammer. Immanuel Nobel had exploded his mines by fusing them with an initial, minor explosion. Why not use an ordinary gunpowder explosion to explode the nitro-glycerine?

Alfred Nobel called his brothers—including the one who lived in Helsingfors—to witness his first large-scale experiment with gunpowder plus nitro-glycerine. 'I filled a glass tube with nitro-glycerine, closed it with a stopper, and put it in a tin can which I filled with gunpowder, inserting a wick fuse into the can,' he described his experiment. 'I lit the fuse, and lowered the whole can in a water ditch. There was a noticeable tremor of the earth and a gush of water: ample proof that not only the gunpowder had exploded but also the nitro-glycerine.'

So there was the new explosive, many times more powerful than gunpowder. But it was a liquid, dangerous to use and most difficult to transport. Still, it was what Alfred's father had wanted. Alfred returned to Stockholm, and more tests were made in the small laboratory which Immanuel Nobel had rented in Heleneborg. Young Emil had also begun to experiment, and discovered that nitro-glycerine could be used by pouring it on gunpowder, thus reinforcing it. The Swedish Army took an interest in the invention, and paid a few thousand *kroner* as an advance so that the Nobels could carry out experiments with guns and shells, but the sum just covered the expenses.

It was Alfred who thought of using the new explosive for peaceful purposes—in mines and quarries. The workers at a great granite quarry in Southern Sweden were amazed at seeing large pieces of rock being hurled into the air by the power of nitro-glycerine. But Alfred was not satisfied. The procedure was as complicated as it was dangerous and unpleasant; the 'fuse', the gunpowder charge, was much bigger than the nitro-glycerine itself, and the glass tube with the oil was a constant source of anxiety.

In the autumn of 1863 he succeeded at last in finding a more practical fuse: a small wooden cylinder with a wick at one end and a gunpowder charge at the other, which was inserted in the glass tube. And eventually he arrived at an even better fuse—a percussion cap, charged with mercury fulminate. The firm was now ready to manufacture the explosive on a commercial scale for blasting granite and for use in the coal mines. At long last, the Nobel family was beginning to see its way out of the wood again. Then one terrible second on that September afternoon in 1864 seemed to put paid to everything: Emil's life . . . the firm . . . the future of the family.

'NOBEL'S SAFETY POWDER'

There was perhaps no point in Alfred Nobel's career at which the strange split in his personality was more evident than after the Heleneborg explosion. The 21-year-old inventor was bitterly reproached by the relatives of the mechanic, the errand boy, the maid, and the workman who had lost their lives. He shook his head: 'It was not my fault. It was inevitable. How can one expect a new explosive to be created without loss of life?'

Yet the same young man could, in another mood, sit down and compose English verses like these:

> '*You say I am a riddle—it may be,*
> *For all of us are riddles unexplained . . .*
> *This breathing clay, what business has it here?*
> *Some petty wants to chain us to the earth,*
> *Some lofty thoughts to lift us to the spheres*
> *And cheat us with that semblance of a soul*
> *To dream of immortality. . . .*'

He had written this poetry under the impact of a tragic love affair. There was a girl, probably his first and last great love, who died only a few months after he had met her. He never spoke about her, never courted another girl, and never married. And the woman who was to exert such a powerful influence on him in his last years was another man's sweetheart and wife.

If Alfred Nobel was sentimental he did not show it after the explosion. The firm had gone; so had the licence to make explosives in Sweden. Within a few months, he had moved to Hamburg—to set up a factory for producing nitro-glycerine!

Within the short space of eight years Alfred Nobel's name, until then completely unknown except in the Heleneborg police files and the creditors' proceedings against his father's bankrupt firm, became a synonym for power—physical power as expressed in the formidable new explosive, and commercial power as exerted by his enterprise all over the world. From Hamburg as his new headquarters, he supplied more and more countries with nitro-glycerine, selling it personally on extensive tours: to Vienna, which was then the administrative centre of the Austro-Hungarian mining industry; to Paris, Italy, London. Germany was his first and best customer. His father and brothers took out patents in Scandinavia and sold Hamburg-made nitro-glycerine. But the tragic and comic incidents which happened everywhere during those first years of the new explosive showed clearly enough its dangers and shortcomings. These stories have something of a Chaplinesque touch.

Nitro-glycerine was transported in zinc can containers, packed in wooden crates stuffed with sawdust. The impurities in the oil often ate little holes in the cans so that it would ooze out into the ships' holds and railway trucks, the horse-drawn vans, the factory floors, or the pit galleries. Sometimes the drivers used it to grease their carriage wheels. In East European mines it was left to freeze in winter, and the miners hacked off lumps for use at the coal face. In Wales an inquest on a man who had been blown up revealed that some miners had played football with the zinc cans. The batman of a Swedish sapper officer used the oil to shine his master's boots.

Bigger and bigger grew the accidents. In Panama, a whole ship blew up; many people were killed at an explosion in Sydney; a warehouse in San Francisco was blown to rubble. Then Alfred Nobel's own nitro-glycerine factory near Hamburg was reduced to ashes by an explosion and fire, followed shortly afterwards by a subsidiary factory which he had established in Norway. One Sunday morning, a German nitro-glycerine traveller's box, which he had left in a New York hotel when he could not pay the bill, was thrown into the street by the hotel porter because it had such an unpleasant smell—and within a hundred yards there was not a window left intact, though in this instance no one was killed.

The press and public were all fire and fury, especially in

America. A Bill was passed by the Senate according to which the manufacturer of nitro-glycerine would, in the event of an accident, be charged with murder and liable to be sentenced to death by hanging. Britain introduced safety regulations which amounted to a virtual ban on the import and manufacture of nitro-glycerine. France and Belgium made the possession of the dangerous oil a crime.

Alfred Nobel saw himself face to face with ruin again. There was only one way out of the dilemma, short of giving up the whole business: that of trying to solidify the oil so that it could be transported with absolute safety. The Hamburg factory was rebuilt while Alfred Nobel continued his search for some solid material with which the oil could be combined.

He did what he could to make shipments safer. Sawdust was obviously not safe enough to protect the cans; it was changed to a special kind of clay which was found all around Hamburg, called *kieselguhr*. It was found to be capable of absorbing oil that leaked out. One day when a can was damaged during packing, Nobel happened to see in the packing-room a little heap of saturated *kieselguhr* powder, which had soaked up an entire can of nitro-glycerine. At once, he took the stuff in his laboratory and tested it. To his joy and amazement it reacted exactly as liquid nitro-glycerine! It blew up when detonated with a percussion cap fuse.

For a year, Nobel experimented with the *kieselguhr*, trying out the most practical methods of manufacture and shipment, and sending samples of the material to his customers for testing in mines and quarries. In 1867, when he was absolutely sure of his new explosive at last, he stopped all sales of nitro-glycerine; the very name of the oil disappeared from the labels and the firm's correspondence, and two new names began to be used instead —names under which Nobel had patented his discovery. One was 'Nobel's Safety Powder'; the other, 'Dynamite'.

THE SECRET WEAPON

The humble clay which Alfred Nobel had used as a packaging material became the solid basis of a business which made him one of the world's richest men within a few years. In America, the 'Atlantic Giant Powder Company' was founded to start the manufacture of dynamite, and thousands of dollars rolled into Nobel's pockets week after week. But it is characteristic of that man with the divided mind that the American business did not interest him at all as soon as the initial difficulties, including a number of lawsuits, had been overcome, and he never visited the United States again after 1866. He remained the principal shareholder of the company, but never wrote any letters to his American associates. The company was later taken over by the DuPont concern. In Europe, the 'Latin Nobel Trust' controlled dynamite manufacturing firms in seven countries; the French company financed all the other companies out of its own fantastically high profits.

In England, Nobel met with many difficulties; the authorities were primarily concerned with safety, but Nobel could point to the fact that he had stopped nitro-glycerine shipments to Britain even before Parliament introduced its safety regulations. He was called before a House of Commons committee as a witness and told the inquiring M.P.'s: 'After the first serious accident was known which could be attributed to the real danger of nitro-glycerine, I immediately stopped making it. I could do no more.' It was true from Nobel's point of view; for all the accidents which made the world resound with protests against nitro-glycerine, except one or two, were in his opinion not due to the dangerous material itself but to careless handling or other circumstances which, he asserted, had nothing to do with the explosive oil.

Eventually, the British Dynamite Company was formed, and made a profit of one thousand per cent within six years. It founded subsidiary companies in every part of the world, and grew into the biggest explosives concern in existence.

In 1870, when Alfred was well on his way towards the first million, old Immanuel Nobel in Stockholm embarked on a new venture. He publicized it in a pamphlet entitled

AN ATTEMPT TO CREATE FULL EMPLOYMENT

To Check Emigration from Sweden

His suggestion was to develop a new industry based on a raw material which he claimed to have invented: sawdust and wood-shavings—waste material from the sawmills—bonded into a new, mouldable substance. He thought that carriages, hat-boxes, 'movable houses', double walls, gas pipes, roofs, suitcases could all be made from it. Furthermore, he suggested that light, cheap coffins could be built from it 'in such a way that a person only seemingly dead could lift the lid himself'. The coffin, specially made for people with a being-buried-alive complex, would also have air-holes and a cord with a bell attached.

He did not, however, live to see his new material introduced in Sweden's industry. It took a number of decades, and the development of plastic bonding substances and manufacturing techniques to turn old Mr Nobel's idea into a practical proposition. He died in 1872; his last invention was a kind of machine-gun, which he dedicated to his son Alfred. 'It will make you the master of mankind in war and peace all over the world,' he wrote in his last letter in a trembling, shaky hand.

But Alfred did not need a machine-gun to build his commercial empire. Dynamite was growing into one of the greatest factors in war and peace. The first dynamite weapons were some German shells fired into the densely populated Paris quarter of Montmartre during the siege of the French capital in 1871: a terrifying experience for the people of Paris who were taken completely by surprise by this new 'secret weapon'. Surely, said those who witnessed the devastating power of these high-explosive shells, surely this must make war impossible from now on—for who would dare to use such a means of wholesale extermination? The fear of reprisals would forbid it.

While the world was still speculating on the possible consequences of the new weapon in international politics, revolutionaries—generally called anarchists in the last quarter of the nineteenth century—were quick in appreciating its possibilities. What a wonderful means of sending a tyrant or some hated political opponents to Kingdom. Come with a minimum of apparatus; what a marvellous scientific achievement compared with the clumsy methods of a Guy Fawkes and his powder barrels!

A Russian group of anti-Tsarist revolutionaries under the leadership of Prince Kropotkin started the dynamite bomb 'fashion' among political would-be assassins. Two attempts were made on Tsar Alexander, two on the German Emperor, one on the Italian King, and a whole series on ruthless capitalists, strike-breakers, and policemen in the United States. It was easy enough to get hold of a few pounds of dynamite; one could buy it straight from the factory, and no questions asked.

For some time, Nobel continued with his experiments. One day he cut his finger in the laboratory, and put some collodion on the wound. But the finger continued to ache, and at four o'clock in the morning he decided that he would do some work as he could not sleep anyway. The collodion—which is made by dissolving nitro-cellulose, or gun-cotton, in ether—had formed a thin film on his finger. As he handled some nitro-glycerine the idea occurred to him: why not combine gun-cotton, the most powerful explosive known before the discovery of nitro-glycerine, with the latter to form a super-high-explosive?

He found the solution of the problem by dissolving gun-cotton in nitro-glycerine. The result was a jelly of even greater explosive power than dynamite. Nobel called it 'blasting gelatine' and later 'cordite'. The great Alpine tunnels—through the Simplon, Arlberg, and St Gotthard—were all built with its help, and indeed could not have been built without it. Later, Nobel turned the 'blasting gelatine' into the ideal high explosive by discovering the means of combining nitro-cellulose and nitro-glycerine in powder form—the smokeless 'ballistite', which came into general use as a propellant for firearms.

SECRETARY FOR A WEEK

Countess Bertha von Kinsky was in distress. As a girl from one of the most distinguished Austrian aristocratic families her path in life was cut out for her, a path fenced in by social restrictions and traditional rules of behaviour. Normally, she would have been married off to some other nobleman, their fortunes and estates combining to assure them a way of life according to their station. But several things had gone wrong. Bertha's father had died when she was quite young, and her mother had developed an unfortunate weakness for gambling. The family fortune was gone within a few years, and mother and daughter were reduced to the unpleasant and embarrassing situation of two aristocratic ladies who had lost the means of carrying on the aristocratic way of life.

A ray of hope, however, appeared in the person of young Prince Adolf von Sayn-Wittgenstein-Hohenstein, who was bold enough to take up the career of a tenor in defiance of tradition and of his family's violent opposition. Moreover, he fell in love with the impoverished Countess von Kinsky, and became engaged to her. But when crossing the Atlantic to sing in America, where he wanted his fiancée to follow him a few weeks later, he died suddenly. So the 33-year-old Bertha saw her last hope of happiness gone. Despairing she decided to take a job and work for her living—a most unaristocratic thing to do. She accepted the position of a companion with Baroness von Suttner and her four daughters, who soon loved her dearly.

But things grew quite different when young Arthur von Suttner, a student at the University of Graz, joined his mother and sisters during vacation. Arthur, a gay, happy-go-lucky fellow who preferred dancing and drinking to attending lectures on jurisprudence, changed completely when he had met Bertha. The good-looking girl with the big dark eyes, the lovely brown hair, and the expressive face with the sad smile—that perfect product of Austria's aristocratic culture—took his heart by storm; and Bertha, a dozen years older than Arthur, returned his affection.

Their love affair had to remain a deep secret, for marriage was out of the question between the penniless Countess Bertha and a member of the family by whom she was employed, although her social standing in the aristocratic hierarchy was theoretically one rung above that of the Suttners, a countess being superior to a mere baroness. But the inevitable happened: one of the Suttner girls saw the two lovers embracing in the garden, and although she told only her sisters the old Baroness grew suspicious, and eventually questioned Bertha. There was only one solution to the problem, prescribed by the code of aristocratic behaviour. Bertha tendered her resignation, and offered never to see Arthur again.

Broken-hearted, she scanned the Viennese newspapers for advertisements to find another job. Her eyes were arrested by these lines:

> 'Elderly, rich, cultured gentleman, residing in Paris, offers job of secretary-housekeeper to mature lady with linguistic qualifications. Box No. . .'

She wrote at once, and received a reply by return of post. The 'elderly gentleman' turned out to be Alfred Nobel. Bertha had never heard of the name—the political and economic developments of the time had never interested her. She accepted the post, and departed for Paris.

Their meeting was a mutual surprise, and a pleasant one at that. The 'elderly gentleman' turned out to be an inconspicuous, shy, very polite little man of 43 with a dark beard of recent growth, a cultured industrialist who was obviously not the type to take advantage of the distressed situation of the Austrian noblewoman. She, on the other hand, was a far more pleasant and charming lady than Nobel may have expected when he advertised for a secretary-housekeeper at a period when only the plainest and ungainliest females were reduced to taking such jobs instead of marrying.

With her womanly instinct, Bertha sensed the strange discord in this man's character. He had moved to Paris a few years earlier to be as near as possible to the geographical centre of his far-flung empire; and he had bought a magnificent *palais* in the heart of that city, a home fit for a millionaire. But he was one of the loneliest men in the world. He had many guests; yet when they had left he was alone with his retorts and his books, his valuable pictures, and the two desks in his study—one reserved for his secretary. That desk had seen many changes, for Alfred Nobel never found what he was looking for.

Now, however, he was sure he had found it. Bertha von Kinsky was the perfect secretary; more, she was the first human being he liked to have about him. Their conversation soon began to touch upon private matters. Bertha told him her story, and that she was still carrying on a secret correspondence with Arthur von Suttner. 'You have acted bravely,' said Nobel. 'But now be completely courageous—break off the correspondence as well. And after a while, a new way of life and new impressions will make you both forget. . . .' But most of the day she was alone, too, and naturally her thoughts returned to the man she still loved. She was very homesick and wept a great deal. Would she ever get used to a life without him?

After a week of her stay at the Nobel *palais* her employer went on a journey to Stockholm, and she was completely alone now. Forty-eight hours after Nobel's departure she received a telegram from Vienna. It read:

CANNOT LIVE WITHOUT YOU ARTHUR

That was all, but it was enough to send Bertha to the nearest jeweller's shop to sell the only valuable thing she had, a diamond cross. It paid for the ticket back to Vienna—to Arthur, and hang the consequences!

'LAY DOWN ARMS'

Within a few days of her arrival at the Austrian capital, Arthur had made all the necessary arrangements for a perfect elopement. They were married in a village church near Vienna, and were soon on board a ship to the Caucasus, where Bertha had friends among the Russian aristocracy who, she hoped, would help Arthur in finding a job. Before departing she wrote to Nobel, apologizing very sincerely for her bad behaviour, and telling him the truth. Soon after the couple's arrival at Gordi, their first Caucasian destination, a letter from Nobel set Bertha's mind at rest. He had nothing to forgive her, he wrote, and wished her all the luck in the world; but he hoped that their paths in life would one day cross again.

By an odd coincidence, Alfred Nobel, too, became increasingly interested in the Caucasus. He invested much of his money in the development of the oilfields around Baku, leaving the practical work to his brothers; but strangely enough he never told

Bertha about this. Arthur could not find a regular job, but was able to make some money by writing for Viennese newspapers. Bertha gave music and language lessons; when her pupils did not pay at once for their lessons the Suttners had nothing to eat and stayed in bed all day.

Suddenly, the evil clouds of war darkened the Caucasian sky. The Turks and the Russians flew at each others' throats again as so often before, and the Caucasus became the main theatre of war. And the usual thing happened—while thousands of men were dying, others profited by the war. Nobel's business soared to new heights. Arthur found employment as a war correspondent for Vienna's biggest newspaper. Bertha's first direct contact with war, although she came from a family of soldiers, shook her very deeply. Her sympathies were with the suffering soldiers and peasants.

By the end of the war, Arthur had made a name for himself as a writer, and now Bertha tried her hand at writing too. She succeeded with her first attempt, and the fee she received paid for some Christmas luxuries, things they had not enjoyed for a long time: a festive meal, rugs, books. . . .

Meanwhile, the Nobel brothers made the Baku region the world's most modern oilfield at the time. In the face of ridicule on the part of their competitors and of much opposition on the part of the native population, they built an eight-mile pipeline to convey the oil to the refineries; armed guards had to be posted all along its length to prevent attempts at sabotage. Alfred, who had never been near an oilfield, invented the method of continuous distillation in the refineries, which is now the standard method; previously, distillation was carried out intermittently, in 'batches', because the usual system of transporting the oil had been to fill it into barrels and load them onto freighters. Alfred Nobel's brothers were responsible for the idea of commissioning a special ship to be built with a large hold solely for carrying oil—the world's first practical tanker. This made continuous distillation at the refinery possible. Within two decades, the Nobels had a tanker fleet of fifty-three vessels at their disposal.

The Suttners found life somewhat easier after Arthur had discovered that he could design houses, which he did all over the Caucasus. But when Bertha received the news that her mother had died, she began to long for a return to the west; and when, in 1885, Arthur's family, much impressed by the courage and stamina of the couple, made the first move toward a reconciliation, they decided to go back to Vienna. They were now both well established as writers, and it was Bertha who suggested a trip to Paris. They saw Alfred Nobel, who appeared 'unchanged, except that he had grown somewhat grey . . . more deeply than ever immersed in his labours and inventions', as she recorded. They talked about books, and it was a casual remark that was to determine the whole of the rest of Baroness von Suttner's life. 'I like novels with a message—propaganda novels,' said Alfred Nobel.

Bertha thought for a long time about these words. She had been turning over a number of ideas for new books in her mind, but she had felt that her gift for influencing others was wasted as long as she wrote merely to entertain people. 'Novels with a message'—why not write them? Why not try to influence the high and mighty, the Nobels of every country, for the good of mankind? There was no doubt in her mind as to what that message should contain. It must be a call for a world war against war—for peace.

She wrote her story in simple, human terms. The form was that of a diary; the writer's name was Martha, but her thoughts were Bertha's, and the man Martha loved, Friedrich by name, was a pen portrait of Arthur: a noble young man of Christian virtues, opposed to violence in every form. Bertha made him a conscientious objector in the Franco-Prussian War; in the end, he was shot by mistake as a spy. She put all the feeling and passion of which she was capable in her book; her description of battle scenes, though gleaned more from newspaper cuttings than from experience, had the ring of authenticity. It was an ardent, intense, highly emotional book, and as such it appealed to the reader's emotions more than to his intellect. The title was a masterpiece of propaganda. Its German original was *Die Waffen nieder!*, 'Lay Down Arms'.

Like all her previous books she offered this one first to newspapers for serialization. To her surprise and dismay, one after the other turned it down—not only in Austria, but all over German-speaking Central Europe. Finally, she sent it to her book publisher in Leipzig, who was under contract to publish all her novels: so he could not refuse this new one. The publisher made excuses. *Die Waffen nieder*, he said, was an impossible title in Germany, with her sabre-rattling young Emperor, Wilhelm II. He also felt that the Baroness did not know enough about politics to write on such a highly controversial subject, and that the manuscript should therefore be 'vetted' by an expert—otherwise the book was liable to be banned in Germany.

Bertha, indignant and more determined than ever to see her work printed, refused to alter it or have it altered by an 'expert'. She insisted on her contract, but waived the usual advance. The publisher had to yield; but he feared that the venture might ruin his business.

PEACE AND THE DYNAMITE KING

Unexpected as the resistance against her work had been to Bertha, its phenomenal success took her even more by surprise. *Die Waffen nieder—A bas les armes—Lay Down Arms* became, within a matter of weeks of its publication in 1889, the most talked-about book in all Europe. Edition after edition was sold out even before the printing ink had time to dry. Parliaments discussed it. Newspapers—including those who had refused to serialize it—devoted whole pages to it. Translations in a dozen languages were made, sponsored by peace societies in as many countries. New pacifist organizations sprang up everywhere under the impact of the book with its pungent three-word title. The Third World Peace Congress, meeting at Rome, elected the Baroness von Suttner its president. But most of all Bertha wanted to hear what the man who had given her the idea, the Dynamite King whose hands controlled the most powerful tools of war, thought of her book. She sent him a copy.

'I have just finished your admirable masterpiece,' he wrote back, but it was no more than a friendly exaggeration, flattering yet non-committal. He had too much trouble of his own. His mother and one of his remaining brothers had died, and his heart had begun to be troublesome. The great Panama Scandal, which shook the French government and society with its frightening revelations of corruption and dishonesty in connexion with the construction of the Panama Canal, made itself felt in Nobel's companies; he was even attacked personally, though without foundation; some of his business associates had been involved in bribery cases without his knowledge. For some time he returned to Hamburg and even thought of staying there for good, but then decided to carry out a complete reorganization of his French enterprises.

Bertha insisted on a more helpful attitude, and wrote to Nobel asking him to put his weight behind the peace movement in France. 'I fear that out of French readers 99 in a hundred are "chauvinists"—they are mad with aggressive patriotism,' he replied evasively. However, he sent her some money for the Peace League funds, and suggested that she should work out an acceptable peace plan to lay before the governments: any dispute between nations should be submitted to arbitration, while the governments concerned should promise to refrain from any hostile action for a 'cooling-off' period of one year.

But Bertha aimed higher, at a general outlawing of war as a means of politics. She seemed quite near that goal when the American President, Harrison, invited all the nations in the world to enter into permanent arbitration agreements with the U.S.A. Still, the Baroness had set her mind on converting the Dynamite King to her cause. The Suttners and Nobel met in Zürich. 'Inform me, convince me,' he told Bertha, 'then I will do something great for your movement!'

Bertha had a week in which to do that job. She took Alfred Nobel at his word. There was hardly an hour of the day or night when she would not talk to him, argue with him, tear his reasonings to shreds, try to sweep him off his feet with her passion for peace. They talked in the hotel lounge, in the gardens and cafés of Zürich, on the motor-launch which Nobel kept on the lake. There was an argument against which Bertha battled with all her strength of mind and passion; Nobel repeated it again and again:

'Perhaps my high explosive factories will end war sooner than your congresses. On the day when two army corps will be able to annihilate each other in a flash, all civilized nations will recoil in horror—and disband their armies.'

'No, they will not,' cried Bertha, 'for each of them will rely on its bigger and better bombs, each of them will try to annihilate the enemy first. We, the peoples of the world, must force our governments to lay down arms!'

Nobel smiled. 'I wish I could prove my theory to you here and now, my dear Baroness. I wish I could produce some material . . . some machine of such terrible power of annihilation and devastation that would make wars altogether impossible——'

'It would not make them impossible, Mr Nobel; that is the horrible truth which we must face. People will go on slaughtering one another, and you armament kings will increase the efficiency of their arms because that's your profitable business.'

'I don't think that a mere increase in the deadliness of weapons would bring world peace, Baroness. A few more soldiers on the battlefields will die—and that's all. No, I am thinking of something more efficient: weapons that will make war as deadly for the civilians at home as for the troops in the front line! Let the sword of Damocles hang over every head, and you will witness a miracle: they will all clamour for peace. But perhaps dynamite is not sufficient to achieve that result, even if one day it will be dropped from the air on the capitals of the world. I think we need something more powerful. Perhaps war would stop instantly if that weapon were bacteria!'

THE NOBEL PRIZE

They parted without reaching agreement. But Bertha knew that the battle was not lost. What Nobel really feared was ridicule. 'To demand disarmament means simply to make a fool of yourself without gaining anything,' he had said. Bertha, being a woman, was free from the fear of appearing too passionate, too emotional about the cause of peace. Her attitude was perhaps naïve and guileless, but it made all the more impression on the public, especially on the women. It was the period of emancipation, and Bertha von Suttner was a shining example of the part a woman could play in the modern world.

When Nobel said good-bye to her in Zürich—never to meet her again—her arguments had already struck root in his mind, though he was too embarrassed to admit it. But he was in fact determined to do 'something great for the movement'. In January 1893, he wrote to her:

'I should like to allot part of my fortune to the formation of a prize fund. . . . This prize would be awarded to the man or woman who had done most to advance the idea of general peace in Europe. I do not refer to disarmament, which can be achieved only by very slow degrees. I do not even necessarily refer to compulsory arbitration between the nations; but what I have in view is that we should soon achieve the result—undoubtedly a practical one—that all states should bind themselves absolutely to take action against the first aggressor. . . .'

In this letter, which foreshadowed ideas that only began to ripen after two world wars, we find a prophecy of frightful accuracy: 'If we have failed at the end of thirty years to reform the present system [of international relations] we shall inevitably revert to barbarism!'

Two years later, in November 1895, he signed his final will. He left the bulk of his fortune, amounting to about £1,750,000 to a trust fund administered by Swedish and Norwegian trustees. The annual interest 'shall be awarded as prizes to those persons who during the previous year have rendered the greatest services to mankind. The interest shall be divided into five equal parts' —now amounting to about £8,000 each—'one of which shall be awarded to the person who has made the most important discovery or invention in the realm of physics, one to the person who has made the most important chemical discovery or improvement, one to the person who has made the most important physiological or medical discovery, one to the person who has produced the most outstanding work of literature, idealistic in character, and one to the person who has done the most or best work for the brotherhood of nations, the abolition or reduction of standing armies, as well as for the formation or popularization of peace congresses.'

The science and literature prizes were to be awarded by Swedish Academies, and the peace prize by a committee of five persons selected by the Norwegian Storthing, the parliament; all prizes were to be distributed, according to Nobel's 'express wish', without regard to nationality, 'to the worthiest, whether Scandinavian or not'. So Nobel had done 'something great', yet without 'making a fool of himself' during his lifetime. He never told Bertha, who was responsible for his decision, how he had carried out her wishes, and left her guessing until the day the testament was opened.

From Zürich, Nobel had gone to San Remo, on the Italian Riviera, where he bought a large estate with a mansion house. He was now in his sixties, a sickly, lonely, rootless millionaire. He fell seriously ill. Confined to his bed he began to write a play in Swedish, a tragedy entitled *Nemesis*. It was a very bad play, and was never performed; but it showed that the Dynamite King would have loved to be an author. Alas, that was one of the things in life he could not have bought with all his money.

His last surviving brother died. Alfred, the weakling, the most delicate member of the family outlived them all. After the burial, which took place in Sweden, Nobel paid a visit to the Stockholm Patent Office where he went straight into the chief engineer's office. The man, an ex-army officer by the name of Salomon August Andrée, looked up from his desk and stared at the visitor.

'Well, Mr Andrée, won't you say good afternoon to me?'

'Mr . . . Mr Nobel! Forgive me, I thought I could not believe my own eyes!'

'I suppose I have changed a great deal since we met the last time, eight years ago. I'm a sick old man. But you look fine—young, healthy, bursting with energy—and still determined to fly to the North Pole?' Alfred Nobel took out his cheque book. 'I've read about this balloon plan of yours in the papers. Perhaps I'd go with you if I were twenty years younger. As it is—' he dipped the pen in the inkpot—'I can only help you with money. How much do you need for that crazy expedition?'

'120,000 *kroner*,' said Andrée.

'Here's 60,000,' said Nobel and wrote the cheque. 'Now go and ask the king for the other half. Tell him I believe you'll do it.'

And indeed King Oscar II, in combination with one or two rich Norwegians, supplied the rest. Andrée began with his preparations. The whole world talked about the great adventure, the attempt to discover the North Pole by balloon. Alfred Nobel took a keen interest in every detail of Andrée's plans.

He was spared the tragic disappointment that was almost inevitable. The frail balloon with Andrée and his two companions, which started in 1897, never returned from its voyage into the eternal ice. But Alfred Nobel had preceded Andrée in death by six months. 'I, who have no heart, figuratively speaking, have one organically, and I am conscious of it,' he wrote in his last letter to Bertha von Suttner. On 10 December 1896, his old butler, his only companion in the large house in San Remo, found him dead at his desk, struck down by a heart attack in the midst of his work. He had died, as he had lived, alone, his hand still on piles of paper dealing with the terrible weapon he had invented. But at the bottom of the deepest drawer was his peace testament, buried under layers of business as his own desire to do good had been buried in his soul until a woman had brought it to the surface.

Nine years later, Bertha von Suttner was awarded the Peace Prize. On 20 June 1914, again nine years later, she died. And one week later, a Serb student shot the Archduke of Austria and his wife during their visit to Sarajevo. The first World War was about to begin. Peace in our time, it seemed, was buried with Bertha von Suttner.

9. *THREE MEN AND A SPORE*

SIR ALEXANDER FLEMING, DR ERNST BORIS CHAIN,
SIR HOWARD FLOREY—AND PENICILLIN

THE young chemist who arrived in England with his little suitcase in March 1933, never wanted to stay in this country. It was Australia that interested him; or perhaps Canada. At any rate, he wanted to turn his back on Europe. It had made his father a refugee many years ago, when Tsarist Russia indulged in the popular sport of *pogrom*, or Jew-baiting; and now it was his own turn. He had left the research laboratory at the University of Berlin as soon as he heard the Storm Troopers, the new masters of Germany after Hitler's appointment as Chancellor, march across the courtyard outside his window. He knew that promising as his scientific career might have been, there was no future for a Russian-born Jew in Nazi Germany.

Dr Ernst Boris Chain had decided to give up chemistry altogether. To be sure, he was only 26; but to continue his studies would have meant starting anew in a strange country, learning a strange language, preparing himself for a new series of difficult examinations, and eventually hunting for a little post in some laboratory in a world where everybody seemed to have degrees and qualifications and introductions. Dr Chain had no money to study again for years—and, above all, he had no patience. Instead, he wanted to become a professional in a sphere in which he had so far been only an enthusiastic amateur: music. He decided to take up piano-playing as his new career—in Australia, or in Canada.

A London refugee committee was already preparing to send Dr Chain overseas for that new start in another part of the world and another profession when it received an inquiry from Cambridge University. A research chemist was wanted urgently. The committee asked Dr Chain.

'But I do not know English,' he said reluctantly.

'Never mind,' he was told. 'You'll pick it up as you go along.'

'And I am only Ph.D. of Berlin University.'

'All right, all right. That's good enough. You can always take another Ph.D. at Cambridge later on.'

And so he did. What he at first regarded as merely a temporary job to fill the time until his departure to Australia or Canada turned out to interest him more than the piano after all. Everybody was kind and helpful, and his great gifts as a research worker were readily appreciated. He picked up the language quicker than he had thought, and the Cambridge Ph.D. presented no difficulty at all. Sometimes, on Sundays, his colleagues asked him to play at private concerts. The long, sensitive fingers which handled the test tubes and microscope knobs with such skill during the week caressed the white and black piano keys, bringing to life the music of Brahms, his favourite composer.

He had been at Cambridge for two years when an Oxford scientist visited the sister university to pick one or two young chemists for a new line of research. His name was Dr Howard Florey, and he had just been appointed Professor of Pathology at Oxford. His aim was to build up an efficient bio-chemical department. Dr Chain seemed to be exactly the man for the job, and from the first moment of their co-operation he and Dr Florey worked hand in glove. They were both interested in, and intrigued by, that little-known field of what we now call 'anti-biotics'—natural substances formed by one kind of bacteria or mould which stop the growth of another.

The story of these anti-biotic substances goes right back to the discovery that bacteria are responsible for a number of diseases. Already Pasteur, the great French pioneer of bacteriology, had discovered that the deadly anthrax bacillus had equally deadly enemies among its own species—bacteria which were able to stop its growth. That was in 1877. Later, other scientists had suggested 'culture treatments' for various diseases in man and beast—the mobilizing of armies of millions of micro-organisms to fight other micro-organisms in the human or animal body. There were masses of literature about this subject, but very few practical results. The recruitment of the anti-bacteria armies seemed just one of those ideas that remain ideas; and most likely Drs Florey and Chain would get bogged down in a field of research which had remained barren for such a long time. Unless, of course, some miracle happened—or at least some chance discovery. And, strangely enough, such miracles have kept happening in the history of science: but only to those who knew how to interpret the signs.

DR FLEMING HAS A COLD

Dr Chain's interest was captivated by the fact that the human body itself produces such bacteria-eating micro-organisms. The man who had discovered them was the bacteriologist at St Mary's Hospital, Paddington. Dr Alexander Fleming, born on a farm among the Ayrshire hills, had been working in that hospital ever since he enrolled there as a medical student. He was a brilliant scientist who had found supreme satisfaction in going about his work within the four walls of an unknown laboratory, except for the years of the first World War when he developed new ways of dealing with septic wounds right behind the front line in France—thereby stirring up much controversy among his colleagues in the medical world.

One day a couple of years after the end of the first World War, Dr Fleming appeared in his laboratory with a streaming cold, and he took a look at his own nasal secretions under the microscope. There seemed to be nothing exciting apart from the staphylococci colonies that were to be expected in such an infection. For three days there were no other microbes to be discovered. On the fourth day, however, he saw to his great surprise a large microbe which he had not seen before—round, opaque, and yellow. He brought it into contact with another drop of mucus from his nose—and it vanished as if by magic.

The powerful agent which dissolved the microbe was, as Dr Fleming found, present in nasal secretions as well as in tears and saliva. He called it 'lysozyme'. It is nature's own cleansing fluid; when we blink our eyes the lids, like a moist rag applied to a window, wipe them clean with lysozyme from the tear glands. Dr Fleming thought he was on the track of a new natural antibiotic; but the lysozyme produced by the human body turned out to be not powerful enough to deal with the more dangerous types of bacteria—otherwise we should never succumb to infections, for the lysozyme would ward them off.

The scientific watchword, never to take anything for granted, was invisibly written all over Dr Florey's and Dr Chain's laboratory. Dr Fleming's paper on his discovery, 'On A Remarkable Bacteriolytic Element found in Tissues and Secretions,' read to the Royal Society in 1922, was the point of departure for the two bio-chemists. Dr Chain decided to make a search of all literature about everything that had been written on 'lysis' and 'lytic agents'—so called because they dissolve (Greek: *luo*) micro-organisms. It was a tremendous task; for weeks on end, he thumbed the pages of innumerable scientific books and periodicals at the Radcliffe Science Library of Oxford University.

Often the whole thing seemed to him rather disappointing. There was very little that had been discovered about lytic substances apart from what Dr Fleming had found. And he was almost on the point of giving up and looking for another, more promising field of research when chance took a hand. 'It was sheer luck that I came across that report in the *British Journal of Experimental Pathology*,' says Dr Chain. 'I am a bio-chemist, not a pathologist, and no chemist would normally think of reading a work on pathology to assist his chemical research. But in Oxford at the School of Pathology the two subjects are combined under one roof, so they are closely linked, and this association led me to go through the journal.'

No one, not even Dr Chain himself, could have anticipated that one of the greatest medical discoveries of our time was hidden behind the dry title of that report in the journal, published ten years earlier, in May 1929: 'The Antibacterial Action of Cultures of a Penicillium with special Reference to their use in the Isolation of B. Influenzae.'

The author was Dr Alexander Fleming.

THE OPEN WINDOW

This report, which is now part of the history of medicine, was, of course, written in an idiom which only the scientist would understand. But Dr Fleming himself puts the story in plain language. 'In 1928,' he says, 'I hit on penicillin. The very first stage in its discovery was due to a stroke of good fortune.'

And the man who 'hit on penicillin' goes on to describe, in greater frankness than any discoverer before him, the state of mind in which such a 'stroke of good fortune' may pass unnoticed: 'If my mind had not been in a reasonably perceptive state, I would not have paid any attention to it. I might have been in a bad temper, say after a quarrel with my wife; I might have just become engaged and my mind might have been full of the young woman, or I might have been suffering from the after-effects of too heavy a meal and been mentally too sluggish to notice it or do anything about it.' And then he states clearly and simply the necessary qualifications of a successful research worker: 'Before you can notice anything strange happening you have got to be a good workman, a master of your craft.'

The week-end before the great day, Dr Fleming was as usual in his cottage at Barton Mills, Suffolk, with its mill-stream at the bottom of the garden. There was an old boat in which he liked to go fishing with his little son—as he had done with his own father in his boyhood in Ayrshire. Or he pottered about in the garden in his old flannels and tweed jacket; sometimes he took his friend and colleague with whom he shared the small laboratory at St Mary's Hospital, Dr E. W. Todd, down to Barton Mills. When Dr Fleming was in the mood he took out his car, and the two scientists delighted in racing the local train!

In the cool and damp summer of 1928, Fleming spent a whole week in Suffolk, and returned in excellent shape of mind and body to his laboratory. Climbing the two flights of stairs with youthful energy belying his 46 years, he found Dr Todd already at work on his staphylococci cultures. Dr Fleming had started a number of such cultures himself before he went away for his holiday: 'colonies' of staphylococci bacteria, 'staphs' for short in laboratory slang. He took one after the other of the shallow glass dishes and looked at samples under the microscope; when taking out a sample from a dish, he had, of course, to remove the glass lid for a short while. 'As soon as you open a culture plate,' says Fleming, 'you are asking for trouble. Things drop from the air.'

This was exactly what happened. Fleming took off a lid; and something came floating in by the open window and settled right in the middle of the 'staphs' culture.

'One of those bits of trouble happened to be penicillin,' says Dr Fleming; 'a mould spore, coming from I don't know where, dropped on the plate. That didn't excite me, I had often seen such contamination before. But what I had never seen before was staphylococci undergoing lysis around the contaminating colony. Obviously, something extraordinary was happening. . . . This was far more interesting to me than staphylococcal research, so I switched promptly. I am now glad that for years my interest had been directed to antiseptics and that some years before I had found in a somewhat similar manner another naturally occurring antiseptic, lysozyme. But for that previous experience it is likely that I would have thrown the plate away as many other bacteriologists must have done before. . . . Instead of casting out the contaminated culture with appropriate language, I made some investigations. . . . There are thousands of different moulds and there are thousands of different bacteria, and that Chance put that mould in the right spot at the right time was like winning the Irish sweep!'

Yet much had to happen before that 'Irish sweep' was really won.

TEN WASTED YEARS

The skeleton of this exciting story was what Dr Chain was able to reconstruct from the pages of the *British Journal of Experimental Pathology*. He looked for the next instalment of that story. But strangely enough—there was no continuation, either in this or any other journal. To be sure, Dr Fleming had made a number of tests with *penicillium notatum*, the mould from which a spore had dropped into the staphs colony, dissolving a round patch of the culture of the size of a two-shilling piece; he made absolutely sure that there could be no mistake before he sat down to write his paper for the Journal. This penicillin, as he called it, had the power of destroying microbes and of arresting their growth.

But there the story came to an end. Penicillin, grown in primitive glass dishes in Dr Fleming's tiny laboratory, weak and impure as a drug, failed to show any sensational results when it was tried out on patients; the best that could be said was that it was no worse than the ordinary antiseptic fluids. Furthermore, it was rather unstable and impossible to transport. Other scientists had tried to develop it—with no better success. Poor Dr Fleming, who kept talking about his penicillin at St Mary's, felt as 'a lone individual—more or less alone', he confesses. Even Dr Todd became a little tired of listening to his colleague's stories. People thought Fleming was riding his hobby-horse to death.

'I collected a couple of juniors in a lab. and we did a little bit of work and got as far as we could,' says Dr Fleming. 'And then we got completely stuck—short of chemical knowledge.'

And so ten years went by; ten wasted years. We dare not think what amount of human suffering might have been alleviated, how many lives saved, how many limbs cured, if the second chapter in the story of penicillin had begun where the first ended. But as it was that fresh start was made only on the day in 1938 when Dr Chain read Dr Fleming's report in the Radcliffe Library at Oxford. 'I made up my mind to see what I could find out about penicillin,' says Dr Chain. He spoke at once to Dr Florey about it.

Dr Florey, who was an Australian with all the energy and intensity of that nation, listened carefully to Dr Chain's reasons for believing that this penicillin was worth investigating. It was a purely academic research subject—there was no question of attempting to make a sensational discovery, of trying to find a new drug that would save innumerable lives and limbs. The two scientists would have refused to believe that in a few years' time their names, linked with that of Fleming and penicillin, would have become household words all over the world.

Florey hesitated. The two men walked home that night, discussing the question of their choice of a research subject. They both remembered later that they happened to stand under a huge elm tree at the entrance to one of Oxford's lovely parks when they decided to take up penicillin.

Next morning, Dr Chain looked into one of the laboratories where a girl assistant tended the various cultures of moulds and bacteria.

'I say, have you ever heard of a mould called *penicillium notatum*?' he asked.

'You mean the fungus that produces penicillin? Yes, of course, we've got it here; we've used it for working with virus,' she said.

'Really?' Dr Chain was delighted; that was a lucky chance. 'How did you get it in the first place?'

'Well, we got it years ago from Dr Fleming at St Mary's Hospital in London.'

This was a good omen. The very mould from Dr Fleming's laboratory was at Dr Chain's and Dr Florey's disposal. Chance did indeed play an important part in the drama of the discovery of penicillin. And so the two Oxford scientists went to work.

THE MICE THAT LIVED

'Although everybody else had failed with penicillin so far, I felt that something could be done if it was handled carefully,' says Dr Chain. 'If it was unstable in heat I could work with it at low temperatures; if unstable in the atmosphere I could exclude the air. And if it was a sensitive protein I could apply protein chemistry methods which I had learned in Berlin.'

Chain and Florey sought the advice of a third research worker at the bio-chemical department, Dr Norman Heatley, a young Cambridge graduate who had an almost uncanny gift for micro-chemical measurement. He suggested a new laboratory technique for the production of crude penicillin from the mould; it was to become famous as the 'Oxford Cup Method'. But before he was able to develop his ideas he received notification that he had been granted a Rockefeller Fellowship to work at Copenhagen University for a year. Such a chance does not come very often in the life of a young scientist, and much as he would have liked to stay and help his colleagues he said good-bye to them and packed his bags.

But history intervened and prevented Dr Heatley from leaving; for the war broke out, and Florey and Chain saw him return to the laboratory on the Monday morning after the fateful Sunday, September 3. From that day, Heatley concentrated all his efforts on solving the innumerable problems which the scientists encountered in their work with the penicillin mould. Heatley was responsible for growing it, Chain for extracting the drug from the mould, and Florey for the biological tests.

Dr Chain found that the penicillin had to be extracted rapidly at a low temperature with ether and acid solution. The result was a salt which could be dried and was stable in this form. What remained was a small pinch of inconspicuous brown powder—the first salt of penicillin, crude penicillin. Today, the scientists who carried out the work know that this brown powder contained only one per cent of penicillin! Yet Dr Florey saw that even this drug, in a solution of one part to half a million, had amazing powers. It stopped the deadly 'staphs' unfailingly. Florey found that it was quite harmless to mice and to warm-blooded animals generally. The time was ripe for carrying out a decisive test.

Hitler's armies were battling their way towards Dunkirk when, one Saturday morning late in May 1940, the great experiment began. Florey had eight white mice brought up to the laboratory, and injected mortal doses of streptococci—the dangerous brothers of the dangerous 'staphs'—into all of them. An hour later, while the bacteria were firmly entrenched in the animals' bodies, he injected a small amount of penicillin solution into four of the mice. Two mice did not receive any more, but the other two were given five injections at intervals.

Dr Florey and Dr Heatley stayed all Saturday and late into the night to watch the experiment. The four mice which had received their penicillin appeared quite happy. The other four soon showed signs of sickness; they all died in the small hours of the morning. The other four lived. The two which had been given five injections were as normal as could be; the two which had received only one were a little listless. But they, too, lived.

The miracle had happened.

Early on Sunday morning, Dr Chain came into the laboratory. He did not have to ask. One look at the cages showed him the result. He turned to Florey, who was resting on a shake-down. 'That's good,' said Dr Chain. He could not say more.

In the meantime, Heatley had gone home after the four mice had died to get some rest. Deep in thought, he pedalled along on his bicycle through the deserted streets. Suddenly a voice shouted, 'Halt! Who goes there?' He nearly fell off his vehicle. A watchful Home Guard stood barring his way. 'And what are you doing at this time of night?' Oh . . . nothing . . . just going home,' he muttered. The suspicious Home Guard looked at his papers and let him continue. One never knew in those days, with the threat of invasion hanging over England. There might be spies even in peaceful Oxford.

Dr Heatley wondered later if he should not have let that Home Guard in on his great secret—that he had been the first person to observe in action the most powerful drug ever known to man.

THE POLICEMAN AND THE BOY

Eight weeks later Dr Fleming opened his copy of *The Lancet*, one of the leading medical journals, at the breakfast table in his Chelsea home. Ah, another article about penicillin, he thought, reading the title, *Penicillin as a Chemotherapeutic Agent*. Probably another record of failure. . . . He never finished his breakfast that morning. The first glance at this article in which the Oxford team reported on their experiments told him that here, at last, was success. He went to his desk and rang Oxford, the School of Pathology. 'Congratulations,' he said. 'But why didn't you tell me——?'

'Well, we might have failed, Dr Fleming,' said Dr Chain. 'And we didn't want to disappoint you. It's nicer to let you know this way, isn't it?'

He went to Oxford to see for himself. 'You're very lucky that Dr Chain decided to investigate the mould,' one of the research workers in the laboratory told him. Fleming agreed.

As there was now no doubt that penicillin was the most powerful drug against infections ever known, production on a larger scale was now an urgent task. The drug had to be tested on human patients, and as soon as possible supplied on a large scale to the fighting forces. The war was not, in fact, responsible for the development of the drug—Chain and Florey would have done their work in exactly the same way, war or no war; but the thought that thousands of lives were in daily danger from infections through enemy action did much to impress on the Oxford team the necessity of working out a method of mass production without delay.

The Oxford team was enlarged by recruiting a number of girls —the 'Penicillin Girls', as they were called: laboratory assistants, students, nurses from various departments, colleges, and hospitals. A number of them worked under Dr Heatley in the refrigeration chamber, wrapped in thick overcoats, with mufflers and ear-flaps, rolling big bottles with mould and ether gently up and down their thighs so that the ether would extract the penicillin. Sometimes, on cold winter days, Dr Heatley appeared on the roof of the laboratory, with galoshes, scarf, and motorist's gloves, to rock the big bottles in the snow. Low temperature was essential in the extraction of penicillin from the mould. It was all a slow and laborious process, and the amount of refined penicillin gained by it rather small. Yet a 'human test' had to be made—soon.

In February 1941, Dr Florey was rung up by Dr Fletcher, a doctor at the Radcliffe Infirmary, Oxford.

'You are looking for a human guinea-pig for your penicillin, aren't you, Florey?'

'Yes, of course. But I don't want to be responsible if—'

'I know what you mean. If the stuff causes any unsuspected dangerous effects. Well, I can satisfy you on that point. The patient is a hopeless case, poor chap. An Oxford policeman. Developed a small sore at the mouth in September; has been at the Radcliffe since October. Generalized blood poisoning; mixed infection of staphylococci and streptococci. The sort of thing your penicillin is supposed to stop. We've operated, we've tried sulfa, we've given him a blood transfusion—it's no use. He's your man, Florey.'

'I'll be right over, Fletcher.'

Dr Florey saw that the policeman was dying. He returned to the laboratory and told Chain and Heatley about the patient. 'How much penicillin have we got?'

'About four and a half grammes. But next week more——'

'There will be no next week for the patient if we can't help him now. I'm prepared to risk every drop of penicillin on him.'

Two hundred milligrammes were injected into the dying man's vein on 12 February 1941. Florey, Chain, and the doctors watched the patient in an atmosphere of great tension while Dr Fletcher felt his pulse and took his temperature. The man shivered a little; but there was no sign of any ill-effect. The injections were repeated every three hours in 100-milligramme doses.

After twenty-four hours the change in the policeman's condition was most spectacular. The temperature was down, the sores on his face were already beginning to heal, his appetite was returning. The deadly bacteria were being beaten back by their mighty enemy. 'Striking improvement,' Dr Florey reported on 'this hopeless case'. For two more days the injections were kept up; but now the penicillin was getting desperately short. Some of it, which had passed with its germ-defeating properties intact through the patient's body, was recovered from his urine—but even this highly unconventional method did not help. There came the sad day when the syringes remained on their tray because there was no more penicillin. Slowly, relentlessly, the bacteria gained the upper hand again. The pitiless poison pulsed through the patient's veins, and there was no more penicillin to stop it. The fever returned, the sores reappeared, the appetite vanished. On 15 March he was dead.

'No more treatments before we have enough penicillin to see the case through,' decided Dr Florey. The policeman's tragedy had made a deep impression on him.

A few weeks later, a boy of 15 was admitted to the Radcliffe Infirmary with a hip wound infection. The doctor rang Florey at once. 'Here's another case. Hæmolytic streptococci. Hopeless if you can't help us. Have you got enough of your stuff?'

It was touch and go—but the boy was saved. Florey's clinical report said: 'Penicillin therapy was followed by a great improvement in the patient's general condition, in spite of the dose being insufficient to maintain a detectable concentration of penicillin continuously in the blood.'

Today, that boy is a healthy man who knows that he owes his life to the three scientists and their indefatigable helpers.

PENICILLIN IN WAR AND PEACE

Penicillin was still far from being a pure drug. Dr Chain spent endless hours in the laboratory trying to isolate it completely, and to discover the secret of its structure. Five years after he had begun his research work he succeeded at last, after innumerable failures. He obtained the 100 per cent pure extract, and he discovered—in October, 1943—its chemical structure. He had achieved what he had set out to do in 1938.

The war was still raging. England was under nightly bombardment. The nation's resources were strained to the utmost. The Oxford team came to the conclusion that there was no hope of organizing in Britain the mass production of the miracle drug. In 1941, after the Radcliffe experiences, Florey and Heatley went to the United States, invited by the Rockefeller Foundation, with a sample of mould in their suitcase. They 'sold' the idea of producing penicillin to America with its vast industrial resources—but the term selling must not be taken too literally. For these men were scientists, interested only in helping mankind to benefit from their discovery. The notion that what they carried in their suitcase was a potential money-spinner of the first order never entered their heads. As scientists they would have scorned any suggestion that they should take out patents for it. The Americans, on the other hand, are a practical people. They built up a huge penicillin industry. And they took out patents for the whole manufacturing process. Today, Britain has to pay them for the right of using those methods to manufacture penicillin.

The miracle drug played a great part in the last and bloodiest stages of the second World War. 'It has had a romantic career,' wrote Dr Fleming. 'Born in times of peace by a stray mould-spore implanting itself on a microbic culture where it was not wanted, it reached maturity at the height of the greatest of all wars, when it was there to help the wounded soldier, and do its part in preventing the awful miseries resulting from septic infections such as were seen in the last and in all past wars.'

In 1945, Dr Fleming, Dr Florey and Dr Chain shared the Nobel Prize for medicine. A year earlier, Fleming and Florey had been knighted; no such honour was bestowed on Dr Chain, the exile. He urged the British authorities to establish an international institute of microbiology so that England should retain the lead in that science, which the discovery of penicillin had given to the country. There was little response; but the Italians were quicker to take up the idea, and when the International Institute of Microbiology was established in Rome the Italian Government invited Dr Chain to become its research director.

So he set off to yet another country of exile, to learn yet another strange language, and to make his home, for the third time, in a foreign metropolis.

Little is known about Sir Alexander Fleming's private life—he always wanted it that way. But all the world wished him luck when, in 1953, at the age of 71, he married 40-year-old Dr Amalia Coutsouris, four years after his first wife had died. Amalia Coutsouris, a Greek doctor, had been imprisoned by the Germans during the war for helping Allied servicemen to escape from Greece. She worked with Sir Alexander soon after the war, for she, too, was a bacteriologist of unusual qualities.

There is no plaque in St Mary's Hospital in Paddington to mark the place where penicillin was discovered. The room where the unwanted spore 'spoilt' Sir Alexander Fleming's culture is now a spare bedroom for doctors on night duty; it is just big enough to hold two camp beds. Visitors may find a card with an inscription on the door; but it does not relate to the discovery of penicillin. It says: 'Cat in residence'.

10. *PACK MULE OF THE AIR*

IGOR SIKORSKY AND THE HELICOPTER

THE four-engined flying boat was returning from its test flight over New York. It was a beautiful autumn day in 1931, the air was calm, and the big machine moved smoothly into the setting sun, describing an elegant half-circle around the skyscrapers of Manhattan.

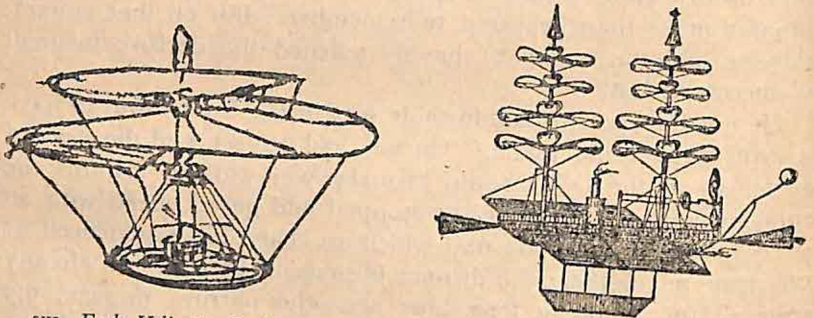
A small group of people had been invited to take part in this flight: the Board of Directors of Pan-American Airways, the company to which the 'plane was now being delivered, a few official guests, and the chief designers and engineers of the firm which had built it, Sikorsky Aircraft. The group also included Mr Igor Sikorsky, whose fortieth, and until that time most ambitious, aeroplane this machine was—the first to be called 'American Clipper'. It was one of the great days in a life which had seen many ups and downs, many dramatic episodes, and more troubles and disappointments than he cared to remember. But on that autumn day he had the feeling of having reached the decisive moment of success at last.

He got up from his comfortable seat in the front cabin to have a stroll through the 'plane. The sun had just set, and the steward switched on the lights while Sikorsky was walking towards the smoking lounge. Suddenly he stopped and gazed ahead with an overwhelming sensation—one which we have all experienced at one time or another: the distinct impression that he had already seen all this before a long time ago—the narrow passage, the bluish lights, the elegant walnut trimmings on the walls and doors, together with the feeling of smooth motion. . . . Psychologists have tried to explain to us how this curious sensation is created, and why we can never recall the precise occasion when and where we have 'seen it all before'. We are told that it is just a trick which our subconscious mind plays on us.

But Sikorsky knew exactly, after the first moment of amazement had passed, where he had received the same impression before. Thirty years earlier, as a boy of 11, he had seen and felt it all in a dream, down to the last detail. The dream was so vivid and exciting that he remained under its spell for several days. He was walking along a narrow passage with walnut panelling, bluish lamps shed a pleasant light, and he felt a slight vibration under his feet, but different from that on a ship or in a train. And in his dream he knew where he was: on board a large flying machine. When he reached the end of the passage and opened a door leading to a beautiful lounge he woke up.

A BOYHOOD IN RUSSIA

The curious thing about that prophetic dream was that it happened to the boy in the year 1900—three years before the Wright brothers' aeroplane made its first successful flight. He had been told that none of the innumerable inventors who had tried to build heavier-than-air machines had succeeded, and that it was generally regarded as impossible that men could ever learn to fly in such contraptions. The dream had been his answer to that problem. It told him: let the experts, the scientists, the engineers doubt if such an invention will ever be possible—if you believe in it you can make it come true.



VII. *Early Helicopter Designs.* LEFT: Leonardo da Vinci's drawing (*c.* 1500); RIGHT: a French inventor's design for a steam-driven helicopter (19th century).

Professor Sikorsky, of the St Vladimir University in Kiev, had chosen a difficult, mysterious, and slightly suspect branch of the sciences as his special field: psychology. The way in which he brought up his three daughters and two sons shows that he had mastered his profession, and knew how to apply it to everyday life. Observing that his youngest son, Igor, had a special leaning towards technical subjects he explained to him the fundamental laws of physics, astronomy, and electricity so that the boy really understood them. But it was his mother who told him first of Leonardo da Vinci, the great Italian artist and scientist of the fifteenth century, who had designed—on paper—a flying machine, leaving its actual construction to later generations. That was the beginning of his passion for flying. He asked everybody questions about flying, and grew very angry when people laughed and said that there would never be anything like a heavier-than-air machine.

Igor had decided for himself, at the age of 10, that flying would be his aim and career in life. He was not at all worried by the fact that there was no such means of transport yet—the unsafe, unreliable, unsteerable air balloon could not be called that. What worried him really was his bad health, which seemed to spoil his chances of a flyer's career. He was a delicate boy; running or cycling usually made his nose bleed for hours. This, of course, did not stop him from taking up several hobbies. He tinkered with electrical things, making batteries and even building a small electric motor; he made chemical experiments, and when he read the description of a bomb which had been thrown by anarchists, he proceeded to make one himself. He bought the necessary chemicals, put them in a small bottle, used a drop of acid as a fuse. The bomb was exploded in a hole which he dug at the bottom of the garden out of everybody's earshot. It was a beautiful explosion, with much fire and smoke and sand being blown up into the air. Needless to say that bigger and better bombs followed.

Igor's parents did not know of this latest hobby of his, but one day the foreman of a group of workers employed on neighbouring grounds complained to the professor about the boy's activities. When the man had explained what Igor had been doing, the professor was unable to hide a smile. 'Look here,' he said, 'I don't think you are in any danger of being hurt by one of these "bombs"!'

'It's not that,' said the man, 'but my men keep leaving their work to look over the fence and watch your son's experiments!'

So Igor was told to stop making bombs. The next thing he turned to was aeroplanes. He built a number of models and tried to make them fly. The strange thing was that he concentrated his efforts on a type of aircraft which was later to assume such importance in his life—the helicopter. Leonardo da Vinci's drawings had given him the idea. The word 'helicopter' is a combination of two Greek words, *helix*, screw or spiral, and *pteron*, wing. It is, therefore, a flying machine which has screws instead of wings. 'If this instrument made with a *helix* is well constructed,' Leonardo had written, 'and the *helix* is turned with great speed, it should be able to screw itself up into the air and rise high.' The idea has been used in the so-called 'Chinese top', a popular toy which came to Europe from the Orient in the nineteenth century. It was a little propeller on a rod with a screw thread; when the propeller was pushed up the rod it started to turn quickly, and after leaving the rod 'screwed' itself through the air. The Wright brothers were given such a toy helicopter when they were boys, and it turned their minds to the idea of building aeroplanes.[1]

Little Igor Sikorsky would have felt proud had he known that great scientists and clever inventors of the not-so-distant past had grappled with the same problem and made the same experiments. Around 1800, Sir George Cayley, the British physicist, built a model which 'rose as high as ninety feet in the air', as he says in his notes. His contemporaries, however, called Sir George with his strange experiments 'crazy as a tight-rope walker'. Today he is recognized as the father of aeronautics, for he was the first scientist to study and discover the aerodynamic forces involved in the flight of birds, which he engraved on a silver disc in the form of a diagram when he was 26. The disc can still be seen in the Science Museum in South Kensington, London; the reverse shows his prophetic vision of a glider 'plane.

All through the nineteenth century, inventors had attempted to build helicopter flying machines: two Frenchmen, who thought it could be worked by hand-operated cranks; an American, who suggested its use as a bomber in the Civil War; an Italian, who succeeded in making his steam-powered model rise to a height of forty feet; another Frenchman, who used an electric motor; a German and an Austrian inventor; and even the great Edison, who thought of employing gun-cotton explosions as a source of power! It was, therefore, a nice achievement of young Igor that he succeeded in making his helicopter model, operated with a piece of elastic, rise in the air; thus he joined, at the early age of 12, the distinguished group of research workers in this field.

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[1] The story of the Wright brothers is contained in *Men Who Changed The World*, by Egon Larsen (Phoenix House, 1952).

AN 'AERONAUTICS SCHOOL' IN 1908

Early in 1909, a 19-year-old student of the Polytechnic Institute at Kiev arrived in Paris for what he thought would be a short visit. The trip across Europe had an extraordinary purpose: he wanted to buy a petrol engine for a helicopter of his own design. Igor Sikorsky had money enough for this purchase—so much money, in fact, that at home in Kiev they had chaffed him about the most likely ways in which he would spend it in the metropolis of amusement. But Olga, Igor's older sister, trusted him; for it was her money he had taken to Paris.

That lad had developed a single-mindedness towards which one could take only one of two attitudes; either laugh about it—or admire it. For years, his thoughts had centred on flying machines. Accounts of the flights made by Count Zeppelin, a German officer-inventor, with his sausage-shaped dirigible airships, and of the Wright brothers' thrilling exploits with heavier-than-air machines had strengthened his determination to be one of that new generation of flying men. But he preferred to think of a type of aeroplane different from that of the Wrights; he wanted to build a helicopter. During a holiday in Germany in the summer of 1908, he began to design such a machine in his hotel room. 'Only at a much later period,' he wrote in his reminiscences, 'was I able to realize how helpful had been my former training, achieved while I was experimenting, or even playing, with various mechanisms, building models, and so forth. I had already gained the knowledge that an inventor's idea is worth almost nothing unless supported by facts and figures!'

He had hardly arrived in Paris and spoken to the first few people about his plans when disappointment made him almost turn back and take the next train home. For he learned that he would not be the first man to rise in a helicopter; a French engineer, Louis Bréguet, had forestalled him in August 1907, and piloted the first man-carrying helicopter, a machine with four airscrews. However, after building a second machine Bréguet had dropped his experiments with helicopters, and returned to fixed-wing designs. Still, Sikorsky told himself that this should not depress but encourage him. Bréguet had proved that vertical flight was possible. The young Russian was sure that he could build a better machine than Bréguet, who had thrown his own on the scrap-heap.

Sikorsky got his first glimpse of actual aeroplanes on the field near Paris where the French inventors were busy trying out their contraptions. It was here that he met Captain Ferber, one of the early pioneers of flying. He told him about his plans. Ferber shook his head.

'You're wasting your time, my lad. The future belongs to the aeroplane with fixed wings.'

'I think I have invented a helicopter that will prove its worth,' said Sikorsky, and took a bunch of drawings from his pocket.

Captain Ferber smiled. 'We have collected some experience here, you know,' he said. 'To invent a flying machine, that's nothing; to build it, that's little; to make it fly—that's everything!' And after a moment's reflection he added: 'Why don't you go to the new School of Aeronautics?'

That school, which Sikorsky entered for a short course, was unique. The fee was modest; there were no entrance or final examinations, no diplomas, and no definite curriculum—not even regular courses, for the students would assemble informally in one of the hangars, listen to what the teacher said or stray around the machines, and usually start a discussion about something that just happened to crop up. The strangest thing about this aeronautics school was that the curriculum did not include a single flight—for none of the owners of the machines, who were all the inventors, constructors, and pilots of their own aeroplanes, could guarantee to take passengers, since machines, weather, technical supplies and so on were completely unreliable. It was left to the students of the school to make their own arrangements if they could. Sikorsky could not; and so he left the school, the airfield, and Paris, without having flown!

But he brought back to Kiev a three-cylinder, 25-h.p. engine which he had bought from the maker, Mr Anzani, a sportsman and designer of racing motor-cycles, who had a small shop in a suburb of Paris. Here Sikorsky met another customer who had also ordered a 25-h.p. engine, a certain Monsieur Blériot; and a few months later Sikorsky read in the papers that Blériot had been the first airman to cross the English Channel—with that same engine powering his monoplane.

THE FIRST FLIGHT

Captain Ferber had not succeeded in discouraging the young inventor from building his helicopter. So he started work in May 1909. He was not yet 20, and he had no experience, but much enthusiasm. The machine was a kind of large wooden box with the engine on one side and the pilot's seat on the other. Pulleys and shafts were intended to transmit the power of the engine to a couple of two-bladed horizontal propellers, one on top of the other, fifteen or sixteen feet in diameter, which rotated in opposite directions.

The first test showed a number of troubles, especially too much vibration; the young inventor cured them one by one, but during the course of these weeks of work he had to come to the disappointing conclusion that this machine could never fly. Its highest lifting capacity was about 350 lbs., but it weighed 450! After a summer spent tinkering with his first helicopter, Igor Sikorsky decided to take it to pieces and build a new one—a better one. The experience he had gained during that summer was invaluable: no textbook could have given him that knowledge and engineering information. And when the winter came he built his Anzani engine into a sleigh and furnished it with a propeller to drive it over the sparkling snow—a fascinating sport!

In the spring which followed, helicopter No. 2 was completed. It looked like an enormous butterfly. It could almost fly—but only almost. It might have risen a few feet into the air without its operator, but the inventor decided that a good deal more knowledge about propellers was what he needed most of all. However, he was weary of building aeroplanes without being able to fly, so he began to make a new machine—a fixed-wing aeroplane of a more conventional design.

'S-1,' Sikorsky's aeroplane No. 1, was the proud name which the 21-year-old aircraft designer gave his machine—a small, light biplane with the propeller behind the pilot. It could taxi across the field quite merrily, sometimes obeying the rudder and sometimes not; but it could not get up into the air. A year and a half had gone by with building and testing flying machines that refused to fly, and Olga's money was completely spent. He asked her what he should do, expecting a bitter remark about waste and pipe-dreams.

'I'll tell you what to do,' said Olga. 'Carry on.'

'Carry on? But, Olga—the money——'

'Leave that to me, Igor. I'll talk father into giving you what you need to make an aeroplane . . . one that can fly.'

'So you believe that I can build one?'

'I most certainly do.'

And Igor carried on. S-1 was disassembled, and S-2 built with some of the parts. One morning in June 1910, the new machine was rolled out of its hangar. Igor climbed into the pilot's seat between the two wings of the biplane, and shouted that magic word of flying men: 'Contact!'

The engine started quickly. Three men held the 'plane. The pilot opened the throttle, and felt the full propeller blast at the back of his head. The engine sounded 'good'. He gave the signal to let go, and the S-2 began to roll across the grass. The tail went up. Igor, who had never flown in all his life, not even as a passenger, took all his courage in his hands and moved the stick back.

A second later he was up in the air. With his heart beating like mad, he tried to remember the necessary movements—a thousand times he had done them in his dreams, in his imagination. Now it was reality: he could feel the machine 'hang' on the stick, respond to every delicate movement. For a time that seemed to be an eternity he held the machine in the air—at two to four feet above the ground. Then, for some reason, the machine decided to return to earth. As soon as he felt the wheels touch the ground he cut the ignition. His first flight was over. It had lasted for twelve seconds—exactly as long as the first flight of the Wright brothers.

. . . AND THE FIRST CRASH

Many pioneers of flight lost their lives, which was not surprising considering that each of their machines was practically a new invention—aerodynamics was based on pure guess-work, the control of the 'planes was haphazard, and there was no other way of testing a design or learning to fly but to 'take her up'. The surprising thing is that some of the pioneers managed to survive —for crashes were almost a routine matter.

Young Sikorsky tried his machine out for a few weeks. It landed too heavily or too suddenly a few times, breaking this or that part. After repairs, he took the machine up again. These flights were short and straight; for in order to return to the point of departure he would have had to fly across a ravine with a swamp at its bottom and cross a river.

This he prepared to do one afternoon. The little machine climbed easily to an altitude of about 80 feet above the swamp —higher than ever before. It was a wonderful feeling of floating in the air. Sikorsky began to make his first circle. But in his preoccupation with the controls he did not notice that slowly the swamp was 'moving up'. He pulled the stick—with the result that the descent only became faster. The next moment the machine crashed against the slope of the ravine. The airman climbed out of the mass of twisted metal and broken wood, none the worse for his accident apart from a few bruises. But the aeroplane was wrecked beyond repair.

Timid souls might have taken this as a warning, and turned to some less dangerous occupation. For the pioneers of flight, such thoughts were completely out of the question. Sikorsky, still backed by Olga and the rest of the family, made another trip to Paris, returning with a 40-h.p. Anzani engine; and after three months of incessant work, the S-3—bigger and better than its predecessors—was ready for the first flight. This machine proved to be highly successful A dozen take-offs and landings were made without any trouble or awkward incidents.

Airmen, like most sportsmen, are superstitious. Sikorsky did not like the idea of making his thirteenth flight in the S-3 on 13 December. But he told himself not to be silly. The weather —it was a clear, sunny winter day with hard frost—was perfect. So he took off. He climbed to a hundred feet. The airfield was left far behind. Suddenly, however, the engine seemed to be losing power. The machine came down. He made a perfect emergency landing . . . on a frozen pond. Unfortunately, the ice was not thick enough to carry the aeroplane. It broke, and the airman found himself completely under water—still sitting in his pilot's seat behind the motor.

He managed to crawl up and out of the icy water. But for the machine, the thirteenth flight had been the last. Again, a chunk of the family fortune had been irretrievably lost. The young aircraft designer-cum-pilot wrestled with his conscience. The money he had spent had been earned by hard work; it was his father's savings and Olga's modest income as a school-teacher. Yet they did not say: 'Give up,' not even now. In order to enable him to continue his work, an extra mortgage was put on the Sikorskys' house. But he realized that this was the very last help he could expect, and if he was unable to build an efficient machine all the money invested in him and in his aeroplanes had to be written off.

S-4 and S-5 were built simultaneously: a light craft and a heavy one. The estimates of the cost of construction turned out to be too optimistic; as a last resort, Sikorsky had to ask some friends for personal loans.

Very early one morning in May 1911, the 22-year-old aircraft designer took his new, heavy S-5 up for the first time; he wanted to escape the curious looks and ironic remarks of the small crowd of loafers who used to gather as soon as they heard an engine running. The machine climbed to about three hundred feet—much higher than he had intended to go. He described a perfect circle and made an equally perfect landing on the airfield. This, at last, was really flying, with a well-built, efficient craft.

GIANTS OF THE AIR

From this day, events moved fast. Sikorsky was allowed to participate in the manœuvres of the Russian army near Kiev, and succeeded in staying up in the air with his S-5 for one hour, reaching a height of fifteen hundred feet. This flight caused a sensation among the army officers, for no Russian 'plane had done so well before, and Sikorsky was presented to the Czar. A few months later, a big railway wagon factory in Petrograd, which wanted to take up large-scale aircraft production, made him their chief engineer and designer, with salary and royalties, and bought from him the exclusive rights of his latest 'plane. At last the years of painstaking work, of danger and disappointment and sacrifice, brought their reward. Olga was prouder than even Igor himself; she had known all along that one day her brother would prove his worth.

One cold autumn evening in 1912, Sikorsky had dinner with the boss of his factory. The conversation naturally centred around flying, and the young man was bold enough to develop his ideas about the future of aviation. Aeroplanes, he explained, must be much bigger and more powerful—giants of the air with closed cabins for a dozen or more passengers and with four engines. The boss listened, and eventually Sikorsky revealed that he had already been working on such a design, which must have sounded fantastic. The great man's reply came totally unexpected.

'All right,' he said. 'Start at once and build your giant!'

Six months later, the first aeroplane in the world with four engines made its successful start, despite gloomy forecasts by everybody that it would be too heavy to rise, too large to be effectively controlled, and that a pilot in a closed cabin could not possibly steer it because he could not feel the air stream—which was regarded as essential. The 'Grand', as the machine was called, presented a completely new approach to aircraft designing and piloting. It weighed nine thousand pounds, had a span of ninety-two feet, four 100-h.p. engines, a luxuriously decorated passenger cabin, two pilots' seats with double control, and even a toilet!

This machine and the next one, which was even bigger—beating the world record by carrying sixteen passengers—made flying history in the years 1913 and 1914. Private cabins with berths, electric light and heating were unheard-of requirements in an aeroplane, only ten years after the first machine had gained the air. Regular passenger and mail services seemed nearer than even the most sanguine enthusiast had hoped.

But then the first World War broke out, and at once fierce battles were fought on Russian territory. For the first time, the aeroplane made its appearance over the battlefields. Sikorsky's big 'planes were tested for their ability to carry bombs, and soon a whole fleet of four-engined bombers—the only 'planes of that size taking part in the war—was built from Sikorsky's designs; about half of them carried out a total of four hundred air-raids on German positions and supply bases, with only a single machine lost.

Sikorsky, still in his twenties, was already on the top rung of the ladder. His father cautioned him. 'My philosophy is optimism,' he said. 'However, as a psychologist I must warn you that success provokes not only praise and applause but, as a rule, also envy and hatred.' There was not much time for those who envied the young inventor to start intrigues against him, for in the spring of 1917 the Russian revolution began, and within a few months Russia had completely dropped out of the war.

In 1918 Igor Sikorsky made up his mind. The country, in the throes of violent upheavals, starving, bankrupt, unsafe, was unable to offer him a continuation of his career. He decided to leave everything behind and emigrate to a safer and more prosperous land. He got a passport and the necessary visas, left Petrograd by rail for Murmansk, and boarded a small British steamer bound for Newcastle. All he had were a few hundred pounds sterling and unshakable confidence in himself as one of the most experienced and skilled aircraft designers in the world. And so, in March 1919, he landed in New York.

A NEW START IN THE NEW WORLD

America, however, was by no means prepared to roll out the red carpet for Mr Sikorsky, who was just one of thousands of Russian immigrants—each of whom claimed to have been the cat's whiskers back home, or at least a Grand Duke. The months went by; he was unable to get a job in the aircraft industry, and his money was running away fast. Soon it became clear to him that any kind of work, suitable or not, would have to be taken up to keep body and soul together.

At last friends secured him a modest position as a mathematics teacher at a school for Russian immigrants on New York's East Side. The fee was just enough to enable him to scrape through; but what embittered him most of all was that he had to start again at the bottom rung of the ladder, and the wrong ladder at that. He had no ambition to make teaching his new career. Sometimes he took a trip to one of the airfields around New York to watch the 'planes, and he felt bitterly disappointed and depressed that he was no longer invited to take part in the development of this wonderful invention, the aeroplane. At night, in his little furnished room, he drew sketches and worked out designs for a new machine, which he called S-29—for it would be his twenty-ninth if it were ever to be built. He had almost lost hope when the turn of the tide swept him on again.

His lectures had brought him in touch with a great many people, some of whom were most interested in aviation and believed that Sikorsky could become a top-ranking designer again if given the chance; and they gave it to him. A share company, the 'Sikorsky Aero Engineering Corporation' was formed in 1923 by these people of modest means. Shares were sold at ten dollars each, and some enthusiasts who had no money volunteered to help as mechanics or labourers. The object of the company was the construction of the S-29, an all-metal, twin-engined airliner.

Work started on the farm of another Russian immigrant, with very primitive equipment—the first items being a pair of home-made aluminium scissors, a hand drill-press, and several objects bought for a few cents from a neighbouring junk yard, an old motor-car bumper, some discarded bed-springs, and similar treasures. From a chain store the 'company' bought some five-cent turn-buckle couplings sold as army surplus goods for radio aerials.

More than once the whole enterprise seemed to be on the rocks; new 'shareholders' had to be enlisted, but they were hard to find. The man who eventually saved the scheme from complete collapse was Sikorsky's great compatriot, Serge Rachmaninoff, the famous composer and pianist, who subscribed five thousand dollars. Despite this generous help the handful of men working on the aircraft often laboured for weeks on end without salary or even pocket money.

In April 1924, the S-29 was ready, and one fine morning Sikorsky climbed into the cockpit. He wanted to take only three of his men as passengers, but seven or eight crowded into the cabin. He did not have the heart to tell these men who had worked so loyally for him to get out. The engines were started. Slowly and reluctantly the machine rose into the air. After a few minutes' flight, the engines—second-hand war-time motors—began to lose power. Sikorsky managed to make an emergency landing on a rough golf course. The 'plane was seriously damaged. It's the end—that was the inevitable conclusion.

But now that Sikorsky was sure that only the mistake of over-loading had caused the damage he decided to make yet another attempt. Without money, they repaired the machine. Even food was a major problem. But many a modest meal was bought for them by the newspapermen visiting the airfield—without their knowing: for by some lucky accident, the telephone bill had been paid in advance; the reporters, who used the hangar telephone frequently because it was the only one in the neighbourhood, paid for their calls on the spot, and with the money Sikorsky and his men bought some milk and bread! They were, of course, much too proud to let the journalists know that it was their telephone cents which kept the team alive.

The last effort to get the necessary funds for construction was an invitation to a group of Russians whom Sikorsky knew to be the loyal core of his 'corporation'. As soon as they had crowded into the small office, he walked to the door, turned the key, and put it in his pocket.

'That door,' he declared solemnly, 'will not be opened until you have subscribed another two thousand five hundred dollars!'

There was a hubbub of indignant voices, but in the end they took it as a joke and subscribed the $2,500. With this money, Sikorsky bought the engines and got the 'plane ready for testing. This time he knew he could rely on his machine. He carried no more than three men, and the S-29 took off. After ten minutes' uneventful flight—which any airman prefers to 'thrilling' incidents—the 'plane landed without a hitch.

The moment Sikorsky climbed from his seat was the happiest he had experienced in the New World so far. He was back in flying, back where he belonged. But what followed was even more gratifying. For this machine, built with the savings of Russian immigrants from junk-yard parts with home-made tools, created a sensation. It was the fore-runner of the twin-engined airliner of the 'thirties. It was the first twin-engined machine capable of flying on one engine if the other developed trouble, which increased the safety margin by a hundred per cent. It could carry sixteen passengers at relatively low cost, and thus proved that commercial transport in the air was not just a luxury for the wealthy few.

The first job offered to the S-29, however, was somewhat surprising. It brought the company its first five hundred dollars for flying two grand pianos from New York to Washington! The newspapers made big headlines out of this story. Sikorsky was 'in the news'.

RETURN TO THE HELICOPTER

From that day he never looked back. Sikorsky 'planes conquered the air. They made air travel an everyday routine. The Sikorsky Corporation grew to be one of the biggest and most successful aircraft production companies in the world. Sikorsky became a close friend of Charles A. Lindbergh, who piloted the first aeroplane that crossed the Altantic Ocean in 1927; two years later, he carried the first airmail from North to South America in a Sikorsky flying boat. And then came that memorable day when Igor Sikorsky boarded his S-40, the first 'American Clipper'—to find that, in the literal sense of the phrase, his dream had come true.

As his designs developed, so did Sikorsky the man. Nobody, so the saying goes, can jump over his own shadow. Sikorsky, a product of European education and background, never grew into the 'hard-headed' American-type of businessman—as he might have done with a purely American upbringing. The greater his success, and the more he 'was worth' in terms of money, the less he cared about it. Time and again he realized how right his father had been when he told the boy: 'A true man must do his work honestly and wholeheartedly, and if he does that he need not worry about the reward. Money and recognition will come of their own accord.'

Sikorsky has always believed in intuition, in the creative spark that alone can breathe life into schemes and blueprints. To his mind, that human faculty has something mysterious, something of the 'fourth dimension' which, he thinks, man should and will learn to master. As far back as 1938, he prophesied that the aircraft of the future would be driven by jets, powered by atomic energy; he forecast the atomic space rocket, carrying pioneers of inter-planetary travel to unknown worlds—unless, he warned, the march of progress were interrupted 'by the destructive foolishness of man himself'.

Early in 1941, after an interval of thirty years, Sikorsky returned to his very first scheme, the helicopter; and it was in this field of aircraft construction that he was to reach the height of his successful career. Strangely enough, all the many inventors who had tried to build helicopters in these intervening years had made very little progress.

Another Russian exile, George de Bothezat, had reached America about the same time as Sikorsky. He described himself, not exactly modestly, as 'the world's greatest scientist and mathematician'. However, his theoretical work on the possibilities of vertical flight was really outstanding, and the American Army commissioned him in 1921 to build its first helicopter. It was a grotesque-looking contraption with four enormous, six-bladed propellers; and it could fly, though its path was determined more by the wind than by the pilot. It cost the army budget two hundred thousand dollars; and when it became clear that much more money, perhaps millions, would have had to be spent in perfecting de Bothezat's machine, the whole project was abandoned. The inventor was the unhappiest man in the world—friends and strangers made fun of him and of his dream which had turned out to be a nightmare.

There was a young Spanish engineer, Juan de la Cierva, among the host of inventors who attempted to tackle the problem of vertical flight. He modified the helicopter idea by turning to the gyroplane, and called his machine the autogiro. It had an ordinary propeller to pull it forward through the air and a large, horizontal one instead of normal wings, like the helicopter; but while the latter's horizontal propeller is always power-driven, that of the autogiro keeps turning only by the force of the air acting upon it, like the wings of a windmill. It sustains the machine in the air and serves to control its position—lateral and longitudinal—in the air, but there is a normal rudder to control the direction of flight. De la Cierva built a number of models in the 'twenties, and proved that his machine was extremely safe, especially at slow speed; it is still extensively used for many purposes. But it is not a helicopter, permitting unrestricted vertical flight; it is an aeroplane with a 'free-wheeling', horizontal rotor instead of fixed wings.

The German aircraft designers at the Focke works succeeded in building a practical helicopter—probably the first in the world—in 1938; it reached a height of 11,500 feet and was powered by a 150-h.p. engine. Two years later the same test pilot, Bode, broke his own helicopter altitude record with an improved 1,000-h.p. prototype by ascending to nearly 23,400 feet. But design and performance of that machine—the Focke 223—were kept secret because of the war, and did not become known outside Germany until 1945.

When Sikorsky, at the age of 52, decided to take up his work on the helicopter where he had left off as a young man of 22, he knew exactly what he wanted his machine to do. Theoretically, the invention had been made over and over again; the helicopter had been described, by designers and engineers, as an aircraft with neither fixed wings nor thrust propeller, but a power-driven rotor. This rotor not only lifts the machine up but also drives it forward, steers it to some extent, balances it, and keeps it hovering. It has, as a rule, three blades, whose 'pitch'—the angle at which they 'bite' into the air—is controlled by the pilot, who can also change the 'tilt' of the rotor axis. Pitch and tilt make the machine rise or descend, move forward or backward or sideways. It has also a small vertical propeller at the tip of its tail, the 'auxiliary rotor'; this controls the direction of flight and counteracts 'torque', that is, the tendency of the helicopter to turn with its rotor.

A simple machine—in theory; the only kind of aircraft which can stay at any point in mid-air, which needs no more than a few feet of ground to take off or land, and is completely free from any space requirements except a little room to swing its rotors. It can land on a roof top, or in water if fitted with floats, on a snowy mountain or in a jungle clearing, on ice or in your back yard. In short, it is—to quote Sikorsky—the pack mule of the air.

In practice, however, this machine is not simple at all but a most complicated piece of mechanism; and that was the reason why so many inventors failed to find the answers to all the problems involved, and why there was so little progress during the thirty years it took Sikorsky to move forward from his second to his third helicopter.

What a difference between these two machines! The outsize butterfly of 1910 with its spluttering Anzani had become a steel skeleton housing a very powerful engine; into its construction and design had gone not only the enormous experience Sikorsky had gained in building fixed-wing aircraft for three decades, but also that extra spark of creative intuition in which he believed so strongly, and with which he had developed his helicopter—on paper—for ten years.

'WEAR IT YOURSELF!'

In December 1941—the month when Japan attacked Pearl Harbour—a secret machine was wheeled out from its closely-guarded hangar at the Sikorsky aircraft plant in Bridgeport, Connecticut. It was the XR-4, the American Army's first modern helicopter, built by Sikorsky. Leslie Morris, his chief test pilot, mounted the cockpit. The large rotor above his head began to turn, and a moment later the machine rose vertically into the air with the elegance of a large bird.

It was the first day of a series of tests which extended over four months. In April 1942, a group of senior officers from all branches of the armed forces assembled on the same field to watch a demonstration 'of the first successful helicopter in the U.S.', as Morris told them proudly. Igor Sikorsky, who stood beside him, smiled and said nothing.

Morris began with a few vertical ascents and descents. He 'jumped up' to about seven feet and held the machine motionless in mid-air. Then he flew sideways, which looked almost unbelievable. He flew backward, made it climb up and down like a lift, and eventually landed in exactly the same grooves which the wheels had formed before the start.

A British Wing-Commander, who was present as an observer, was the first to speak. 'Well, this beats anything I've ever seen,' he said. An American Major said: 'That thing will do anything a horse can do!' And someone at the back of the group kept shaking his head: 'If I hadn't seen this with my own eyes I'd say it's impossible.'

Igor Sikorsky smiled and said nothing.

Morris mounted the cockpit again. He had prepared a little 'encore', a few stunts to show the incredible accuracy of flight which this machine could achieve. A pole, eight feet high, was placed in the field, and a brass ring attached to its top. The XR-4 rose, moved slowly to the pole, hovered just above it, and inched down a little. Morris put out his hand, holding a little steel tube, with which he took off the ring from the pole at the first attempt. Then the craft moved back to where Sikorsky was standing, came down within a yard of the inventor's head, and Morris handed him the ring.

'Now watch this!' shouted Morris from his cockpit. A small bag with a dozen eggs was suspended on a ten-foot rope underneath the helicopter. It rose slowly, circled for a minute with the bag hanging from the machine—and then descended with great delicacy, placing the bag on the ground.

One of Sikorsky's men opened it and showed the onlookers that not a single egg was broken. 'They must be hard-boiled,' said one of the officers, took one out, and looked at it quizzically. Sikorsky's chief designer took the egg and cracked it on a stone without saying a word. It was raw.

Next, a telephone wire was extended between the ground and the helicopter in the air, and a conversation—probably the first of its kind—was carried on with a passenger in the helicopter. Eventually, Morris opened the cabin door, rolled out a rope-ladder, one of Sikorsky's men climbed up the twenty-odd feet, and disappeared through the door of the cabin, which was then shut.

'I always wanted to see the Indian rope trick,' cracked one of the officers. 'With this machine I could do it myself!'

The helicopter had come to stay.

Igor Sikorsky himself established the world endurance record by staying in the air in his XR-4 for over an hour and a half two weeks later. Then came the greatest test. The Army asked him to deliver his machine at Dayton, 760 miles from Bridgeport, *by air*. It was a leisurely trip with more than a dozen stops, and it took five days. The people who saw the strange craft flying, landing, or taking off rubbed their eyes. One airfield guard came up and asked Morris, 'I don't believe what I've just seen. I know it's a secret ship, but may I look again when you take off?' A group of aircraft spotters rang up the Civil Defence centre in New York and reported that a weird-looking foreign machine was hovering over military installations, apparently taking photographs by the hundred. Another spotter reported: 'A farmer's windmill's just passed overhead!' At one stop the sirens began to wail and the ambulances to race to the airfield when the helicopter descended vertically. They expected a crash. 'You scared the hell out of us,' said the airfield commander when, contrary to his expectations, Morris and his passengers climbed out of the machine completely unhurt. On a field somewhere between Albany and Utica, a farmer pointed his shot-gun at the machine, and Morris decided to climb out of range as fast as he could—the fellow down there meant business.

The job of landing on a crowded airfield was no problem for this machine. Once Morris touched down on a spot where another 'plane was going to be parked, and an airfield attendant was sent over to guide him to another parking lot. 'You just go ahead,' said Morris, and the helicopter followed the bewildered man at walking pace just like a horse being led on a rein. In Buffalo, Morris made the people on the airfield gasp by purposely overshooting the ramp by ten yards—and then flying back to set the craft down elegantly.

'I've seen them do everything,' said an officer after watching this performance, 'but I never saw one back up!'

At Cleveland, Igor Sikorsky met 'his baby', excitedly asking questions about the performance of the machine. Then he climbed into the cabin and took the stick over from Morris for the rest of the trip to Dayton. Everybody had felt so safe with this machine that there was only a single parachute, which Morris was wearing. For even with its engine out of order the air stream would keep the rotor turning, braking the fall of the machine, so that it could effect a smooth landing.

Morris slipped off his parachute and put it on the pilot's seat so that Sikorsky should have a cushion. Sikorsky did not like this at all. 'Les,' he asked Morris, 'how old are you?'

'Thirty-three.'

'So you have nearly twenty more years to live before you're as old as I am now. Take your parachute and wear it yourself!'

THE FUTURE OF THE HELICOPTER

Igor Sikorsky had again reached his goal, though only he and his closest collaborators knew how much toil and sweat it had cost to create the 'pack mule of the air', the first efficient 'direct-lift' aircraft. For months on end they designed and re-designed every part of it until they were able to make the first modest 'hops'; they attached ropes to the controls and worked them from the ground while the machine, pilotless, was in the air. Endless trouble was taken to make this a really perfect and safe craft.

'I have never been in the air in a machine that was as pleasant to fly as the helicopter,' says Sikorsky. 'It is like a dream to feel the machine lift you gently up in the air, float smoothly over one spot for indefinite periods, move up or down under good control, as well as move not only forward or backward but in any direction.'

Sikorsky's machines were the only helicopters used by America during the second World War, and when peace came a whole new range of possibilities for the new type of aircraft opened up. Sikorsky predicted that by 1960 it would have proved to be a faithful servant of the peaceful progress of humanity in innumerable ways; it would make the world bigger—as the long-range aeroplane had made it smaller: residential areas would expand, for a man could easily live with his family some distance from his place of work, and get there every morning quickly by direct-lift aircraft. 'No other instrument,' wrote Sikorsky in 1941, 'could contribute as much towards helping persons in need, or saving lives under the most adverse conditions.'

Two years later, the truth of this prediction was borne out in a most dramatic way. An explosion in an American destroyer off the New Jersey coast injured a number of sailors. Only the immediate supply of blood plasma gave them a chance to live. It arrived by helicopter. Since that day, thousands of lives have been saved by this craft. During the great flood disaster of 1953 in England and Holland, the British Admiralty placed a dozen helicopters at the disposal of the Dutch rescuers: British and American fliers between them flew one thousand eight hundred people, who may otherwise have been drowned, out of the danger areas. The machines picked them out of trees, off narrow window ledges, and from other precarious spots. It was the acid test of the helicopter as a unique aircraft; no other type could have landed and taken off on these isolated islands surrounded by a storm-swept sea.

Plant diseases have been conquered, crops protected by chemicals sprayed from helicopters. Explorers have charted unknown lands with its help. And in May 1953, a Sikorsky-55 picked up the Duke of Edinburgh from the grounds of Buckingham Palace for an inspection tour.

Two months later the Belgian airlines opened the first regular international passenger services by helicopter between Brussels and Antwerp, Rotterdam, Lille, Maastricht, and Liège; the route was extended to Cologne and Bonn in October 1953. The services are operated with comfortable seven-seater Sikorsky S-55 machines. Passengers and mail are being carried from town centre to town centre, and the coach trip to the airport—which often takes longer than the actual flight from capital to capital by airliner—is eliminated. Sooner or later, most of us will have the experience of flying in a helicopter.

Igor Sikorsky's XR-4 was only the first of many types. England was the second country to take up helicopter development; it was the first to produce a gas-turbine machine, the Fairey Rotodyne, seating forty passengers and cruising at 200 m.p.h., in 1952. Other teams of helicopter designers have built ram-jets into the rotor tips to give the craft additional power. It looks as though the pack mule of the air will be with us for a long time.

11. *A PLAN FOR PLENTY*

HARRY FERGUSON AND HIS TRACTOR

FEW of the delegates to the International Food Conference which met in June 1943, in the middle of the second World War, at Bethesda, Maryland, had heard the name of Harry Ferguson before, a name which appeared on a special invitation to a lecture and demonstration. 'A New Hope for Mankind' was the mysterious title Mr Ferguson had chosen for that address. Ferguson —was it perhaps the man connected with tractors or something? And why should he want to talk to the delegates? They were intrigued; and they went to hear and see Mr Ferguson.

A slightly-built little man with thick, greying hair and piercing eyes behind rimless glasses mounted the dais. He began to speak fast, in a clear, Irish voice.

'I suppose you know that only one invention in ten thousand succeeds,' he said. 'The reason is that there is no plan behind the failures. The one that succeeds has a plan behind it. I am going to tell you of a plan which we have worked out in Northern Ireland, a plan for a revolution in the production costs of the necessities of life. When you know what that plan is, I am sure you are going to approve of it. I know you are going to say it is the most far-reaching plan that man has ever devised.

'To put that plan in effect, machinery must be designed fitted to that plan. Your task today, gentlemen, in the interest of all your countries, is to judge whether the machinery we are going to show you will fit the plan. If the plan be good and the machinery be good, then we have the greatest and best news that you have ever heard. We have a new hope for mankind.'

The delegates from fifty countries, from Britain and Bolivia, from America and Afghanistan, from China and Czechoslovakia, pricked their ears. It was an unusual address, very different from the innumerable speeches they had been sitting through during this and many other conferences; and it was an unusual man who was talking to them.

He was obviously an industrialist bent on selling his product; but at the same time, he was possessed by an idea which seemed to be more important to him than money—he had a plan which he put before profit. And it was a plan of vital interest to the food experts who had assembled to hammer out a post-war policy to establish freedom from want all over the world.

A MACHINE TO ABOLISH WAR

'I made up my mind,' he continued, 'to make a machine to revolutionize agricultural production in the whole world—a tractor. Today, all the companies making tractors are scarcely touching the fringe of farm mechanization. It is hardly born yet. You can judge, today, our plan and our equipment from the standpoint of world conditions.

'Abolition of poverty is our first problem. What is poverty? What is want? They are the inability to buy the bare necessities of life. Many plans have been put forward for solving the problem of poverty. But none of them can succeed unless something be done to create the wealth with which to put those plans into effect. We can never solve the problem of poverty until we can create wealth to a far greater extent than we have ever done in this world before, and until we can stabilize and then reduce prices.

'Now we can do that. We have the means. We are going to show you that today.

'Under the present system of ever-increasing prices we are heading for inflation, for endless bickering and friction between the people of every country. Up go the wages . . . up goes the cost of living . . . up go the wages . . . and so the vicious circle goes on. The result can only be more wars, because so long as people are kept in ferment there will be war. There will be people trying to better themselves through war if they can't do it any other way.

'Our new price-reducing system is a complete revolution. It alters the whole outlook for mankind. But there is only one place to start on the way to prosperity. It is the farm which is the basic cause of the vicious spiral of increasing prices.

'We must revolutionize the methods on the farms of the world. They are hopelessly antiquated. Look at the equipment with which farmers are trying to make a living. Are you not shocked when you see the farmer's machinery today? In the past fifty years the world has progressed more than it did in the fifty thousand years previously. The inventive genius of man turned its attention to industry for producing automobiles, radios, aeroplanes, and so on, and designed equipment for factories to produce at ever-reducing cost. But all this genius has been devoted only to industry—not to the farm. The farmer's equipment has remained more or less as it was hundreds of years ago, and farm mechanization has been introduced only in a very restricted way. There are perhaps no more than two or three million tractors in the whole world, but many millions of horses, mules, oxen, and other draught animals.

'I believe that the world could absorb something like a hundred million tractors.

'Agriculture is more important to mankind than all the other industries in the world put together—yet it is about the only industry which is still being conducted by antiquated methods. Why, gentlemen?

'Because,' and Harry Ferguson thumped the desk with his fist, 'because until now no one has come along with machinery which will do, on all the farms in the world, everything that animals now do—and at a fraction of the cost. It is that machinery you are going to see today. It can bring the cost of living down by half. It will eliminate the system of ever-rising prices, and introduce the price-reducing system. We thereby solve the problems of poverty, friction, insecurity, and take the first practical step towards the abolition of war.'

He took a little model from the desk and held it caressingly in his hands. The delegates bent forward to have a closer look at the machine that was to perform all these miracles.

Until recently, Mr Ferguson explained, all attempts at mechanizing farming started with combination of a tractor and separate implements—that is, two separate and distinct units. The conventional tractor had to be heavy to get traction, and also to make it safe for the man at the wheel. The accent was on power and weight, with injurious effects on the land; it compressed the 'pan', the layer between the top soil and the subsoil, into a hard mass that prevented the water from getting into the subsoil.

With a heavy tractor dragging something behind it, such as a plough, the man at the wheel was never safe; for when the implement met with an obstruction, the energy in the flywheels tended to lift the front of the tractor. The implement was liable to be broken. 'If a farmer breaks an implement,' said Mr Ferguson, 'he can't get on with the job until it is repaired or renewed. If he breaks it in the critical days of spring it may be a disaster for him. Farm machinery should be fool-proof! We spent a fortune in solving that one problem. We will show you how we solved it.'

Mr Ferguson stepped down with his little model, and the delegates gathered around him as he began to explain his invention.

A MOTOR-CAR SPECIALIST AT 16

During the first fifty years of his life, Mr Harry Ferguson was just an unknown participant in the motor-business, and the delegates at the Food Conference must be excused for not knowing much about him; his fame was then only beginning to spread. Motors had been on his brain since he could think. He and they were born at almost the same time, for the patent which started the age of the motor-car, taken out by a South German mechanic by the name of Gottlieb Daimler, was less than a year old when Harry Ferguson was born on a County Down farm in Northern Ireland in 1884.

He might have stayed on his father's farm had it not been for Joe, his elder brother, who set up an engineer's shop in Belfast, and asked Harry to join him, in 1900. What 16-year-old boy would not have grasped that chance with both hands? It was the beginning of the phenomenal rise of the motor-car, and while Joe concentrated on devising and building all kinds of gadgets and appliances for Belfast's factories, Harry specialized in servicing, repairing, and selling motor-cars and motor-cycles. There was no one to teach him the trade; all he had to know he had to learn the hard way, by trial and error, and by taking to pieces and re-assembling as many motors as he could lay hands on.

Three years later, he built his first motor-cycle, and from then on motor-racing was his chief interest for a long time. He entered for every motor-cycle race in Ireland, and won a number of hill-climb and endurance trophies. The short, wiry lad with the imperturbable nerves and the steady hand and eye seemed cut out for racing.

At 23 he raced his own motor-car for the famous Muratti Trophy. It was a two-day reliability test, and Ferguson was the winner—or so he thought. But the committee discovered that it was a dead-heat, and ordered a new contest by the two machines. It was then that Ferguson's pertinacity and single-mindedness, which was to help him build and defend an industrial empire, showed itself for the first time. He refused to accept the committee's decision, for in his opinion he and not the other fellow had won the Muratti Trophy. As Ferguson refused to re-run the race, the committee awarded the prize to his opponent. For Ferguson, it was not so much the prize as the principle involved which made him stick to his guns.

It was well-nigh inevitable that the young man, who was so much in love with the petrol motor, should turn to aeroplanes at the earliest possible moment. And so he did, after he came back from a trip to Paris in 1909, where he had watched the first air show. He designed and built a small monoplane—the first British-made machine, and the first to fly in Ireland, if his hedge-hopping performance of 130 yards near Newcastle, Co. Down, on the last day of 1909 could be called flying.

Harry Ferguson might have become a pioneer of flying and an aircraft industrialist had he not been such a bad pilot. He succeeded only with difficulty in getting his machine in the air again. Once it turned upside down—and not only Harry Ferguson fell out but also the engine. All Ulster laughed about the intrepid airman who kept trying. When the Town Council of Newcastle offered him £200 for a show flight along the beach he was determined to earn the money. He succeeded in flying for three miles, but soon afterwards he was taken to hospital as the result of a bad crash.

He had married Maureen Watson, an Ulster girl from his home town, Dromore, Co. Down, not so long before that, and it was his young wife who made him promise to give up flying. So he returned to repairing and selling motor-cars in Belfast—not to forget racing. By the time the first World War broke out, Harry Ferguson had established a good reputation as a motor expert, and it was this circumstance which was responsible for a decisive turn in his career.

The Irish Department of Agriculture was looking for a capable man to supervise operation and maintenance of all tractors and implements throughout the country to ensure their maximum efficiency, as the food situation was growing more and more difficult in the British Isles. Ferguson, the motor specialist, was offered the job; and that first intimate contact with tractors on the land set him off on the road which eventually led him to the Food Conference at Bethesda almost thirty years later.

THE THREE-POINT LINKAGE

What he saw of existing methods of using tractors on the land during the first World War made him think about the whole problem of mechanical- and animal-power in farming. He came to the conclusion that the animal was barring the way to human progress, and that only efficient mechanization could raise agriculture to the level it must reach if hunger, misery, and poverty were to be abolished for ever.

As soon as the war was over, he designed a plough which could be easily and firmly attached to the most popular tractor of the time, Henry Ford's 'Fordson'. The American automobile king liked the ingenious system of linkage between tractor and plough which the unknown Irishman had invented, and the co-operation between the two 'H.F.'s'—Henry Ford and Harry Ferguson—began under good auspices. Henry Ford would have laughed if someone had told him that one day his firm would have to fight the greatest lawsuit of all times against the man who was trying to do his own modest business in the wake of the world-famous Fordson.

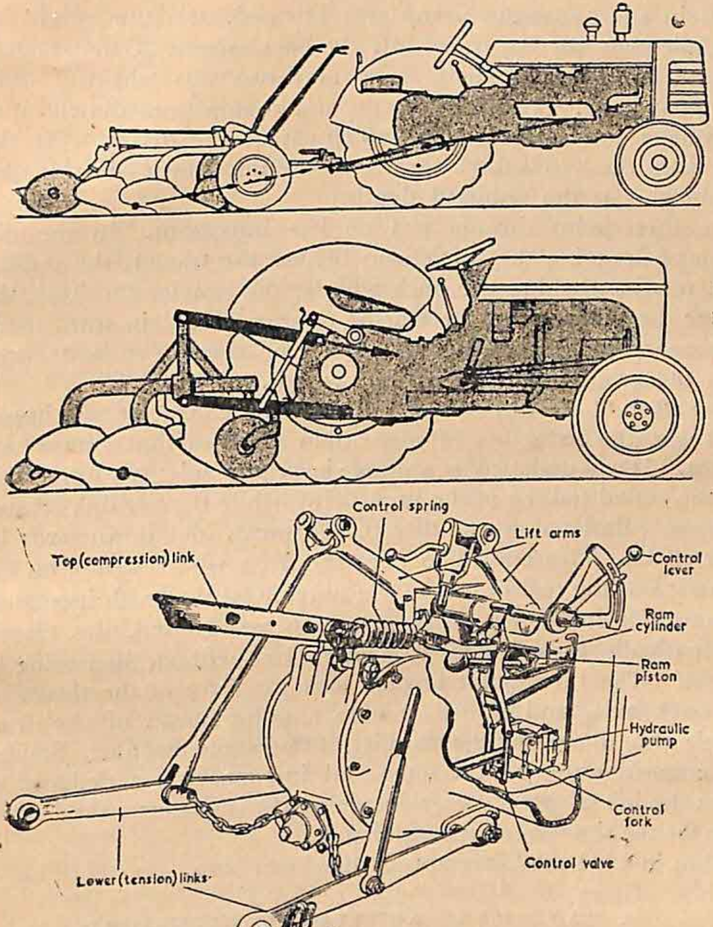
Soon, however, Mr Ferguson's business was no longer modest. His ploughs were very successful, and as early as 1922 he went to America to set up a manufacturing company at Evansville, Indiana. During the first six years of its existence, this factory sold an enormous number of ploughs to Fordson users. What distinguished these implements was the automatic regulation of the depth at which they engaged the soil, and their linkage with the tractor so as to form an integral unit.

One day in 1928, however, Harry Ferguson received a piece of news which would have put many a less persevering man out of business for good. The news was that Ford was stopping manufacture of his tractors—and that therefore no more Ferguson ploughs would be needed! Harry Ferguson did not even realize that he was in a quandary. To him, the way out of this situation was perfectly simple. Ford had stopped making the Fordson. So what? Ferguson would start making the Ferguson!

But it took him six years to arrive at the starting line. For he had his own ideas about tractors and ploughs or other implements, and refused to continue on the same worn-out tracks as his predecessors. The heavy tractor with the implement dragged behind as a separate unit was wrong; the Fordson with the Ferguson plough had been a great improvement; but now the Ferguson system was to supersede them all. In his Belfast workshop, Harry Ferguson and his assistants built a prototype of the new machine by hand, after endless experiments and field trials. With that machine, Harry Ferguson aimed at nothing less than a revolution in agricultural engineering.

It was a light-weight tractor of only 16 cwt., which any orthodox tractor expert would have regarded as ridiculously insufficient to make the attached implement keep to the ground and work. But there were two important innovations. One was the hydraulic lift for the implement, and the other the three-point linkage between tractor and implement.

The hydraulic lift was built into the tractor. It could lift up to a ton, and enabled the farmer to carry the implement in a raised position to and from the place of work; then, by pulling a lever, he lowered the implement to the ground, and the actual work began. The danger of the 'rearing' tractor was overcome by a special device: as soon as the implement struck an obstacle,



VIII. *Harry Ferguson's Tractor.* TOP: Traction—the old way: the pulling point is behind the back wheel, which tends to make the tractor rear up. CENTRE: Ferguson's 3-point linkage—the two lower links do the pulling, and the high hitch-point keeps the front wheels of the tractor on the ground. BOTTOM: Detailed drawing of the Ferguson system.

the oil in the hydraulic pump was released, and the weight of the implement thereby taken off the back wheels of the tractor, while at the same moment an extra thrust was 'thrown' onto the front wheels. Thus the tractor would stop immediately, and no damage was done to the implement or the driver. At the same time, the hydraulic system kept the implement—in this case the plough—at the required depth.

The three-point linkage was no less important. In the old system of dragging the implement behind the tractor, the pulling point was just behind the back wheels; the heavier the load, the greater the tendency of the tractor to rear. This, in turn, made it necessary to increase the weight of the tractor, so as to keep it on the ground with all its four wheels.

The effect of the three-point linkage between tractor and implement was the reduction of more than a ton of that unnecessary weight. It was designed on a simple lever principle: two lower links did the actual pulling of the implement, while the top link created a strong rotational force, directed forwards and downwards by lever effect. This tended to keep the front wheels firmly on the ground; but the real beauty of the system was that with increasing pressure, for instance on a plough in heavy ground, the tractor automatically turned into a 'heavy' one—without increasing its weight! The three-point linkage took the force of the thrust off the back axle, and shifted it onto a point ahead of the front wheels, thus increasing the stability of the whole machine. Besides, the connexion between tractor and implement was designed to make the job of attaching or detaching the implement child's play even for the slowest-witted farmhand.

Thus in 1934 the 'Ferguson System' was born.

A HANDSHAKE AGREEMENT WITH FORD

Farmers are known to be the most conservative people in the world—anywhere in the world. That, of course, was the reason why they had stuck to their traditional methods while industry, transport, communications, and everything else were undergoing revolutionary changes. Harry Ferguson knew very well what he was up against with his tractor. He did not start production until 1936. The sales were small, little progress was made by Ferguson's agents who tried to introduce the new machine, and everywhere the argument was the familiar one: 'What was good enough for my father. . . .'

Europe seemed to be an especially difficult territory; so Ferguson set his hopes on the New World. Early in 1939, he went to America to talk to Ford. The two men had not met before; all the name of Harry Ferguson had meant to the automobile king was that of the small-time plough manufacturer who had trailed behind the Fordson tractor as long as the great man thought fit to produce it, and who had now probably gone to the dogs as so many business people had in the 'thirties, what with slumps and unemployment.

But to Henry Ford's surprise, Harry Ferguson still seemed to be alive and kicking, although he had not sold any Fordson ploughs for ten years or so. When Ferguson asked him for an interview in January 1939, Ford consented to see him, curious to know what the man looked like and what he had to offer. Henry Ford was not an easily impressionable man; but the little Irish fellow, then in his mid-fifties, impressed him tremendously. They were men made of the same stuff, they both combined a supreme sense of business with an idea far beyond the mere purpose of making money.

Ferguson had brought his tractor with him, and demonstrated it to the American. The result was surprising.

'I don't mind telling you,' said Ford, 'that with this machine here you've put yourself on a plane with the world's greatest inventors—with Edison, Bell, and Marconi. Now what is your suggestion?'

'I want you to mass-produce the tractor, Mr Ford, while I sell it to the world.'

A handshake sealed the agreement; no contract was drawn up. Thus Harry Ferguson became the only partner Henry Ford ever had.

Tractors and implements soon began to roll off Henry Ford's production line. During the first three years of the Ferguson System, before the handshake agreement, Ferguson had not made more than a thousand tractors in Huddersfield; from 1939 to 1947, more than three hundred thousand tractors and two million implements were produced by Ford. These implements, integrated with the tractors to a degree that made the two parts a single unit, were designed for all possible kinds of work—there were no less than 160 types: ploughs, tillers, disc and tooth harrows, middle-busters, corn planters, ridgers, cultivators, scoops, stalk cutters, graders, threshers, land levellers, mowers, potato planters and spinners, subsoilers, steerage hoes, weeders—to mention only a few. But there were also large and small trailers and transport boxes, ensilage cutters, loaders, cranes, and even wood-saws. In short, there was hardly a mechanizable kind of farm work which that machine could not do, short of milking the cows and feeding the pigs.

'. . . This machinery is wealth-creating machinery,' the wiry little man continued his address to the Food Conference delegates at Bethesda in 1943 when he had demonstrated his little model to them. 'It will create the wealth with which our populations can buy other manufactured goods, the necessities and comforts of life—and thus enormously increase employment. It will lay the foundations for the complete recovery and reconstruction of the whole world after the war, if it is properly applied and used. I want you to get that vision and share it with me. What, gentlemen, do we seek? Peace and Security, Prosperity and Happiness. With all the sincerity I possess, I tell you that we will attain those splendid things exactly in proportion as we get the farmers of the world to modernize, to mechanize, and to mix their thought with their labour.'

He stood down amid the enthusiastic applause and congratulations of his listeners. Many of them had never heard the name of Harry Ferguson until that day; but all of them were now in agreement that it was a name that would make its mark in the annals of human progress. Harry Ferguson was greatly encouraged by the response he had encountered. These men, he hoped, would go back to their countries, and spread the Ferguson idea all over the world. It was bound to take root. His struggles had brought him forward to a point where victory could already be seen looming in the not-too-distant future. Little did he foresee that within a few years he would have to face the most difficult situation in his career.

BATTLE OF THE GIANTS

The war was over. The ravaged lands were crying out for quick help. Ferguson's tractors, made by Ford, were shipped to all parts of the globe. Where they were introduced, agriculture began to change from a sentence of drudgery to a businesslike way of life. Other manufacturing companies were marketing tractors on kindred hudraulic lift and 'mounted implement' systems; they had proved their worth to the suspicious and hard-headed farmers.

In April 1947, Henry Ford, 83 years old, died[1], leaving his industrial empire to Henry Ford II, his grandson. And within two months the blow fell on Harry Ferguson. The famous handshake agreement had not been enough. The new master at Detroit decided to stop making tractors for Ferguson by the end of June 1947—and to start producing his own. Harry Ferguson was left without a production centre in America and with a shattered selling organization. Fortunately, he was able to make production arrangements with Standard Motors in Coventry; but what had been a thirty-million-pound business in 1946 made less than four million in 1947.

Ferguson's first step was to build, within the record time of 116 days, a 72-acre factory right on Henry Ford II's doorstep in Detroit. Tooling and equipping were accomplished, under his personal supervision, with enormous speed, and in October, 1948 Harry Ferguson drove the first tractor off the production line; meanwhile, his American customers were supplied from Coventry.

His second step was to bring in a lawsuit in New York against Henry Ford II—the most gigantic case ever to be heard in any Court in the world. He sued Ford for the trifle of £89,680,000, alleging that Ford infringed his patent rights and attempted to push him out of the American market, thus trying to set up a monopoly (which is an offence under the U.S. anti-trust laws), while unlawfully seizing and using Ferguson's inventions, engineering techniques, and ideas, and violating the agreement of trust and confidence made in 1939. The case went on for more than four years, becoming the costliest in history. For a time, the American Court moved *en bloc* to England to hear witnesses.

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[1] For the story of Henry Ford I, see *Men Who Changed The World* by Egon Larsen (Phoenix House, London, 1952).

Everybody thought that the case must be worrying Harry Ferguson to death; but, in fact, he enjoyed the giants' battle. 'Worried?' he replied to a friend's question. 'Certainly not. I've never been so happy in all my life!' And when a reporter asked him if he still found time for a hobby, he said, 'Of course I have a hobby. I think about The Case!'

Fantastic sums were offered to him as a settlement out of Court. He declined them. 'It's the principle involved,' he would say. Eventually, in 1952, the judgement was pronounced. £3,303,570 in royalties was granted to Ferguson—only a fraction of what he had asked for, but still the biggest sum of money ever awarded to an inventor. Ford was ordered, by the end of 1952, to stop making the tractor he had been producing since the break with Ferguson in 1947.

Perhaps the most curious part of the judgement concerned a little coupling pin used on a special hitch at the rear of the tractor. By order of the Court, Ford was allowed to sell the pin only as a replacement part on Ford 8N tractors manufactured before November 1949; and a notice to this effect must accompany every such pin sold until 25 October 1966!

The battle of the giants was over.

NOTEBOOKS AND TIES

If you want to get into Harry Ferguson's bad books once for all, you only have to visit him wearing a double-breasted suit with a yellow waistcoat, with a crumpled tie and a half turned-up collar. And to make quite sure that he takes an instant dislike to you, you might just as well wear a pair of suède shoes.

Because of these and many other little fads Harry Ferguson, Britain's tractor king and millionaire industrialist, has often been called an eccentric. But he can explain the reasons for his likes and dislikes. He hates everything that is not 'businesslike'.

Double-breasted suits look baggy, he says; yellow waistcoats and suède shoes introduce, to him, an element of unwarranted nonchalance into the seriousness of a working-day. Neatness, tidiness, cleanliness, punctuality—all these things go together for him. It has happened more than once that he has told one of his directors at a board meeting before the start of the business, 'Put your collar straight!' And the director did put his collar straight without answering back. 'If you yourself are tidy, your business will be tidy too'—that is Harry Ferguson's maxim.

He insists on highly-polished floors throughout his headquarters building in Coventry. A mechanic who came into his view wearing a dirty overall would be liable to be lectured to. 'Nothing must be left to chance,' is another of his mottoes. For instance, the chance that someone might have an idea and forget it must be avoided; for this reason, Ferguson insists that each of his employees, from his private secretary down to the last garage hand, has a notebook in his left-hand outside pocket and a pencil clipped to his left-hand inside pocket. When—or if—some idea occurs to him, he has to whip out notebook and pencil with a single double-movement of his hands, and jot it down. The jotting-down, too, is subject to Ferguson's rules: one idea—one line. He dislikes two-line ideas as much as double-breasted suits.

His eyes behind those rimless glasses seem to see everything. 'They see if you tell a lie,' his employees warn one another. He has no hobby—not since The Case has ended. He never relaxes; he is Harry Ferguson for twenty-four hours in a day, and for seven days in a week. He expects the same of his employees. Why, they might wake up at night and have a brainwave for Harry Ferguson! To cope with this emergency, they are all advised to put their notebooks and pencils on their bedside tables.

'Nobody works *for* me,' he declares. 'They all work *with* me.' But his own capacity for work is immense. He can dictate letters for hours at a stretch without tiring, and without ever fumbling for words: his Irish verbosity is a great help to him there. His private secretary uses up two or three shorthand notebooks per week just taking down letters. These letters are long but clear. Here again, he leaves nothing to chance—the chance of something being overlooked; the subject with which a letter deals must be typed in the middle and underlined, and as soon as another subject is dealt with there comes another sub-heading.

'Beauty is simplicity'—another watchword of his. It goes for engineering (no superfluous parts, perfect suitability for a certain purpose) as well as for advertising (no more than the absolute minimum number of different type-faces or sizes must be used in an advertisement). His private life, the little there is of it, is neat and orderly. He has a comfortable home at Abbotswood, in the Cotswolds. He drinks and smokes rarely. Punctuality rules his day. The only occasions when he has been known to be late at the office were those when he saw from his car a farmer in trouble with his Ferguson tractor: then he would jump out, get his set of tractor tools from the boot of his Bentley, and give the farmer a hand—or an on-the-spot lecture and demonstration.

'Harry Ferguson never sells a tractor; he owns them all,' they used to say when another such incident became known in Coventry. If this were true he would 'own', at the age of 70, about 58 per cent of the world's tractors—nearly a million. To make sure that Ferguson dealers and users know how to get the finest possible performance from each tractor and implement, and can pass this knowledge on to others, a Ferguson School has been established at Stoneleigh Abbey, near Coventry, and other schools in mechanically backward countries, especially in Asia; here, a continuous succession of courses teaches the Ferguson agents and the farmers how to progress on the road towards the goal which Harry Ferguson has set himself.

It seems unlikely that he will ever reach it; unlikely, indeed, that it can ever be reached, because the ills of our world cannot be cured by tractors alone, no matter how many implements they trail behind them. Harry Ferguson's urge for simplification may be the mark of genius in the sphere of engineering, but his desire to see the politicians rally to his ideas will probably remain unfulfilled. However, his crusading zest never impedes his superb business talents. When Pandit Nehru visited England, Harry Ferguson talked to him about his ideas for revolutionizing farming in India; and when Nehru left, Ferguson had sold him thirty tractors!

THE GREAT MERGER

Perhaps Harry Ferguson was disappointed to see that in the years after the second World War a powerful rival was beginning to assume the part he had allotted to his tractor, that of a miracle-working machine producing plenty for all. That rival was the combine harvester.

The story of the 'combine' goes back to 1811, when 12-year-old Daniel Massey was travelling across the vast uncultivated land of what is now the Canadian Province of Ontario with his parents, to settle in that pioneer country and live by farming. For the greater part of his life Daniel Massey struggled to make the soil yield enough for his family to eat. He was nearly 50 when he happened to visit some relatives in the United States and saw a number of new agricultural implements. They were clumsy and costly, but Daniel Massey took them back to Ontario, improved their design, and began to manufacture them by mass-production methods. His son followed in his footsteps, and in the course of the second half of the nineteenth century the firm of Massey became one of Canada's biggest manufacturers of food-producing tools.

It had an equally big competitor, the firm of Harris, also a father-and-son business, at Ingersoll, Lake Ontario. Both companies introduced modern agricultural machines such as the mower, the reaper, and the binder. In 1891, the companies joined to form the Massey-Harris Company. Ten years later the first successful reaper-thresher was tried out, and in 1910 they began to make their appearance in the fields of Ontario, drawn by teams of horses. That was the beginning of the combine harvester, the machine that cuts the corn, threshes it, and puts it into sacks or large tanks while throwing out the straw. But only in 1939 did Massey-Harris market their first self-propelled combine. Shortly afterwards, Britain became engaged in the second World War, with her supply lines exposed to Hitler's U-boats; she had to increase her food production by every means if she wanted to survive. The combine was one of the most powerful helpers in that struggle for survival. It revolutionized Britain's agriculture—a revolution which spread to the Continent immediately after the war.

Harry Ferguson was shrewd enough to recognize the fact that the world's agriculture would need the combine as much as the tractor if it was to feed the hungry millions. He began to work on the design of his own combine harvester and a new large tractor to pull it. But he must have found that he could not hope to catch up with Massey-Harris in their own special field. So he asked Mr James Duncan, the Massey-Harris president, to visit him in Coventry.

One afternoon in summer, 1953, Mr Duncan—a Canadian self-made man who had started at the age of 17 as an office-boy at Massey-Harris—came to see Harry Ferguson, who showed him secretly developed machines. Mr Duncan was very much impressed.

'And what do you suggest?' he asked Ferguson.

'Nothing more and nothing less than a world amalgamation of our two firms,' said the Irishman.

At a day's notice, Duncan brought his co-directors, lawyers, and head representatives over from Canada and the United States; and within a few hours, an agreement for the merging of the interests of the two immense enterprises for the whole world was ready for signing. Thus, in August 1953 the two organizations became a single one under the new name Massey-Harris-Ferguson, and with Harry Ferguson their technical director and Chairman of the Board.

But Ferguson has not been content to limit his great inventive gifts to tractors and combines. At the age of nearly 70, he returned to his first and earliest love—the motor-car. A prototype of the Ferguson Family Car was on the road in 1953, a model likely to be many years ahead of its time when he eventually decides to mass-produce it. All his enormous gifts as an engineer are being bestowed on the design and production of that car. He may be content to make and sell it on its own merits, without the ideological backing of a plan for universal happiness—just as he created the Ulster Tourist Trophy in the 'twenties by getting the

Ulster Parliament to pass the bill which enabled the government to close roads for motor-racing. It was a minor crusade, and Ferguson did not mind that he was never properly credited with that achievement. When the first race was run, he served in the pits in the humble faculty of a depot marshal. He did not mind. The great thing was that he had done what he had set out to do.

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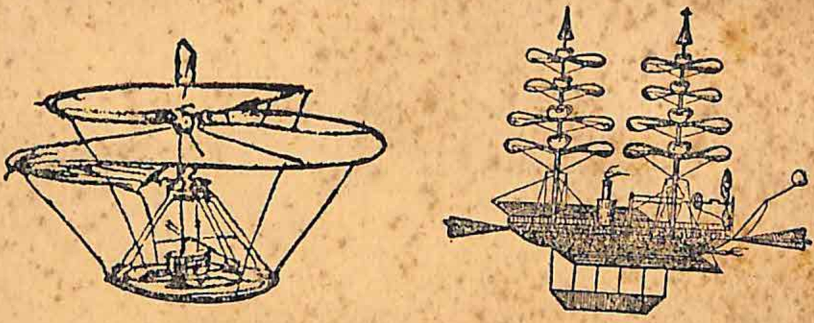

(See page 158)

VII. *Early Helicopter Designs.* LEFT: Leonardo da Vinci's drawing (*c.* 1500); RIGHT: a French inventor's design for a steam-driven helicopter (19th century).

Some Press Notices

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